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World Radio History

NEW ELECTRONIC CONSTRUCTION KITS

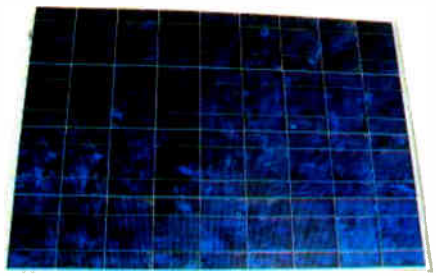
This 30 in 1 electronic kit includes an introduction to electrical and electronic technology. It provides conponents that can be used to make a variety of experiments including Timers and Burglar Alarms. Requires: 3 x AA batteries. £15.00 ref BET1803

AM/FM Radio This kit enables you to learn about electronics and also put this knowledge into practice so you can see and hear the effects. Includes manual with explanations about the components and the electronic principles. Req's: 3 x AA batts. £13 ref BET1801

This **40 in 1 electronic kit** includes an introduction to electrical and electronic technology. It provides conponents that can be used in making basic digital logic circuits, then progresses to using Integrated circuits to make and test a variety of digital circuits, including Flip Flops and Counters. Req's: 4 x AA batteries. £17 ref BET1804

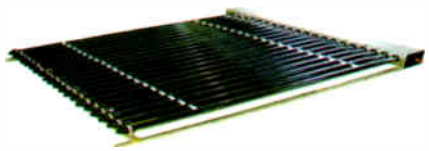
The **75 in 1 electronic kit** includes an nintroduction to electrical and electronic technology. It provides conponents that can be used to make and test a wide variety of experiments including Water Sensors, Logic Circuits and Oscillators. The kit then progresses to the use of an intergrated circuit to produce digital voice and sound recording experiments such as Morning Call and Burglar Alarm. Requires: 3 x AA batteries. £20 ref BET1806

SOLAR PANELS



We stock a range of solar photovoltaic panels. These are polycrystalline panels made from wafers of silicon laminated between an impact-resistant transparent cover and an EVA rear mounting plate. They are constructed with a lightweight anodised aluminium frame which is predrilled for linking to other frames/roof mounting structure, and contain waterproof electrical terminal box on the rear. 5 watt panel £29 ref 5wnav 20 watt panel £99 ref 20wnav 60 watt panel £249 ref 60wnav. Suitable regulator for up to 60 watt panel £20 ref REGNAV

EVACUATED TUBE SOLAR HOT WATER PANELS



(20 tube shown) These top-of-the-range solar panel heat collectors are suitable for heating domestic hot water, swimming pools etc - even in the winter! One unit is adequate for an average household (3-4people), and it is modular, so you can add more if required. A single panel is sufficient for a 200 litre cylinder, but you can fit 2 or more for high water usage, or for heating swimming pools or underfloor heating. Some types of renewable energy are only available in certain locations, however free solar heating is potentially available to almost every house in the UK! Every house should have one -really! And with an overall efficiency of almost 80%, they are much more efficient than electric photovoltaic solar panels (efficiency of 7-15%). Available in 10, 20 and 30 tube versions. 10 tube £199, 20 tube £369, 30 tube £549. Roof mounting kits (10/20 tubes) £12.50, 30 tube mounting kit £15

2kW WIND TURBINE KIT

The 2kW wind turbine is supplied as the following kit: turbine generator 48v three taper/ twisted fibreglass blades & hub 8m tower (four x 2m sections) guylines / anchors / tensioners / clamps foundation steel rectifier 2kW inverter heavy-duty pivot tower. £1,499

Other sizes available from 200 watts (£299) up to 20kW (£13,999) The 200w system is complete apart from 2x12v batteries and concrete for the tower. These low cost systems can provide substantial amounts of power, even in average wind conditions.

STEAM ENGINE KIT

The material in this pack enables you to build a fully functional model steam engine. The main material is brass and the finished machine demonstrates the principle of oscillation. The boiler, uses solid fuel tablets, and is quite safe. All critical parts (boiler, end caps, safety vent etc.) are ready finished to ensure success. The very detailed instruction booklet (25 pages) makes completion of this project possible in a step by step manner. Among the techniques experienced are silver soldering, folding, drilling, fitting and testing. £29.70 ref STEAMKIT Silver solder/flux pack £3.50 ref SSK

HOT AIR MOTOR (Stirling motor) This is an interesting metal based project for pupils aged 15 plus. The material pack will enable them to make a fully functional hot air motor. All the critical parts (piston, working cylinder, flywheel and coolers) have been pre-made and are ready for use. The detailed plans show all the important stages for the required metal working (Measuring with a vernier, sawing, silver soldering, drilling, marking out,thread making, silver soldering, sawing and filing, etc) At the same time the principles of the hot air motor are described in the wide ranging instructions. Technical data : Working cylinder stroke ø 12 x 10 mm Pressure cylinder stroke ø 13 x 11 mm

Unloaded speed approx. 800 rpm Size: Flywheel dia. 55mm Base 130 x130 mm With sinter smooth bearings and ready shaped cooler. £29.70 ref STEAMKIT2 Silversolder pack £3.50 ref SSK

Thermo **Peltier element**, large Size: 40 x 40 x 4,7 mmTechnical data of the Thermo element:Use as a Peltier element to cool or heat: will provide 33 Watts of heating or cooling, max temp difference between sides of 67ºC, maximum output 15V 3,9 Ampere 150ºC 3,5 Ohm 250 mW/K 22 g, 49 mV/K £14 ref TEL1

Die cast illuminated microscope set in plastic carry case Includes a handy carry case with a 1200x magnification microscope. Contents include test tubes, magnifier glass and probe. Requires 2 x AA batteries (not included). ultra-compact, lightweight, easy to use and comfortable to hold. An ideal microscope for the beginner offering a good magnification range. £25.99 ref MAG1200

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STIRLING ENGINES

HB10 One of our range of Stirling engines The Bohm HB10 Stirling engine is available in both ready built and kit form. The power comes from a small spirit burner, once lit just watch this amazing Stirling engine run. HB10 in kit form is £97.95 or £101.99 built. Many other models in stock. Order online at www.mamodspares.co.uk

Rapidos Mobile networking digital surveillance system. Plugs into USB port on computer, takes 4 cameras, NSTC or PAL, 352*288 res, 1-30 f/s MPEG4 & MJPEG, motion detection, pre and post recording, watermark, date, time and location markings, alarm notice via FAX, FTP or email, Modes- continuous record, motion detection record, sheduled record, time lapse record, dynamic IP, can send live images to your mobile phone. £109 ref RAPIDOS

HEAT PUMPS

A heat pump is a system that uses a refrigeration-style compressor to transfer heat from outside to inside, in order to heat offices or homes. Heat pumps can take heat from the air, water or ground. Ground source heat pumps are very efficient – in fact you will get 3-4 units of heat for every unit of electricity supplied to the heat-pump. Basic component parts of a GSHP:

1 A heat pump packaged unit: Water-Water type. (approx. the size of a small fridge) containing two cold water connections and two heated water connections.

2. The heat source which is usually a closed loop of plastic pipe containing water with glycol or common salt to prevent the water from freezing. This pipe is buried in the ground in vertical bore holes or horizontal trenches. The trenches take either straight pipe or coiled (Slinky) pipe, buried about 1.5 to 2m below the surface. A large area is needed for this.

3. The heat distribution system. This is either underfloor heating pipes or conventional radiators of large area connected via normal water pipes.

4. Electrical input and controls. The system will be require an electrical input energy, single phase is perfectly adequate for smaller systems. A specialised controller will be incorporated to provide temperature and timing functions of the system.

This type of installation offers many advantages.

a) The water-water heat pump unit is a sealed and reliable self contained unit.

b) There are no corrosion or degradation issues with buried plastic pipes.

c) The system will continue to provide the same output even during extremely cold spells.

d) The installation is fairly invisible. i.e. no tanks or outside unit to see.

e) No regular maintenance required.

Some tips

The efficiency of any system will be greatly improved if the heated water is kept as low as possible. For this reason, underfloor heating is preferred to radiators. It is vital to ensure that the underfloor layout is designed to use low water temperatures. i.e. plenty of pipe and high flow-rates. If radiators are to be used, they must be large enough. Double the normal sizing (as used with a boiler) is a good starting point.

5Kw (output) ground to air heat pump £1,099 ref HP5

9kw (output) ground to water heat pump £1,999 ref HP9

World Radio History

ISSN 0262 3617

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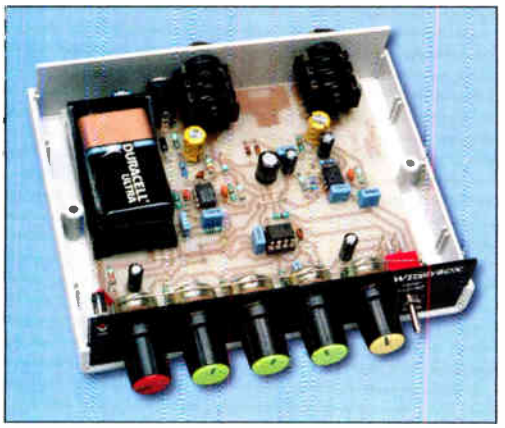

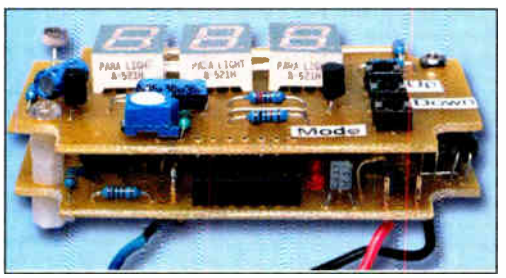

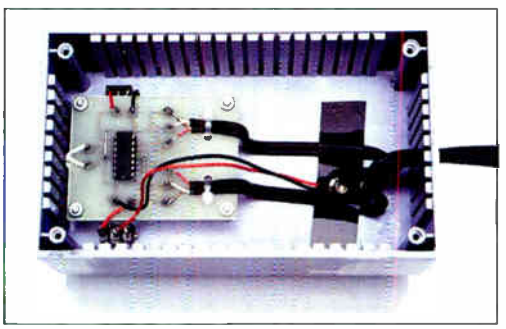

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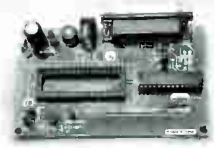
NEW! USB 'Flash' PIC Programmer

USB PIC programmer for most 'Flash' devices. No external power supply making it truly portable. Supplied with box and Windows Software. ZIF Socket and USB Plug A-B lead not incl.
Kit Order Code: 3128KT – **£34.95**
Assembled Order Code: AS3128 – **£39.95**

"PICALL" ISP PIC Programmer



"PICALL" will program virtually all 8 to 40 pin *serial-mode** AND *parallel-mode* (PIC16C5x family)* Programmed PIC micro controllers. Free fully functional software. Blank chip auto detect for super fast bulk programming. Parallel port connection. Supply: 16-18V dc.
Assembled Order Code: AS3117 – **£24.95**

ATMEL 89xxx Programmer

Uses serial port and any standard terminal comms program. 4 LEDs display the status. ZIF sockets not included. Supply: 16VDC.
Kit Order Code: 3123KT – **£29.95**

NEW! USB & Serial Port PIC Programmer

USB/Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket and USB Plug A-B lead extra. 18VDC.
Kit Order Code: 3149KT – **£34.95**
Assembled Order Code: AS3149 – **£49.95**

USB Flash ICSP PIC Programmer

Fully assembled version of our 3128 USB Flasher PIC Programmer but WITHOUT the pre-gramming socket. It just has 5-pin ICSP header (GND, VCC, CLK, DAT, VPP) and cable. No external PSU required. Free Windows software.
Order Code: AS3182 – **£37.95**

ABC Maxi AVR Development Board

The ABC Maxi board has an open architecture design based on Atmel's AVR AT90S8535 RISC microcontroller and is ideal for developing new designs.
Features:
8Kb of In-System Programmable Flash (1000 write/erase cycles) • 512 bytes internal SRAM • 512 bytes EEPROM • 8 analogue inputs (range 0-5V) • 4 Opto-isolated Inputs (I/Os are bi-directional with internal pull-up resistors) • Output buffers can sink 20mA current (direct l.e.d. drive) • 4 x 12A open drain MOSFET outputs • RS485 network connector • 2-16 LCD Connector • 3·5mm Speaker Phone Jack • Supply: 9-12VDC.
The ABC Maxi STARTER PACK includes one assembled Maxi Board, parallel and serial cables, and Windows software CD-ROM featuring an Assembler, BASIC compiler and in-system programmer.
Order Code ABCMAXISP – **£89.95**
The ABC Maxi boards only can also be purchased separately at £69.95 each.

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have.
See website for full details. Suitable PSU for all units: Order Code PSU445 – **£8.95**

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 TXs can be learned by one Rx (kit includes one Tx but more available separately). 4 indicator LEDs.
Rx: PCB 77x85mm, 12VDC/6mA (standby).
Two & Ten Channel versions also available.
Kit Order Code: 3180KIT – **£39.95**
Assembled Order Code: AS3180 – **£47.95**

Computer Temperature Data Logger

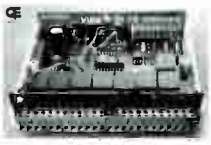
Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four header cables.
Kit Order Code: 3145KT – **£16.95**
Assembled Order Code: AS3145 – **£23.95**
Additional DS1820 Sensors – **£3.95 each**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12VDC.
Kit Order Code: 3140KT – **£39.95**
Assembled Order Code: AS3140 – **£59.95**

Serial Port Isolated I/O Module



Computer controlled 8-channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130 x 100 x 30mm. Power: 12VDC/500mA.
Kit Order Code: 3108KT – **£49.95**
Assembled Order Code: AS3108 – **£59.95**

Infra-red RC 12-Channel Relay Board

Control 12 on-board relays with included infra-red remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12VDC/0·5A.
Kit Order Code: 3142KT – **£39.95**
Assembled Order Code: AS3142 – **£49.95**

PC Data Acquisition & Control Unit

Monitor and log a mixture of analogue and digital inputs and control external devices via the analogue and digital outputs. Monitor pressure, temperature, light intensity, weight, switch state, movement, relays, etc. with the apropriate sensors (not supplied). Data can be processed, stored and the results used to control devices such as motors, sirens, relays, servo motors (up to 11) and two stepper motors.

Features
- 11 Analogue Inputs – 0·5V, 10 bit (5mV/step)
- 16 Digital Inputs – 20V max. Protection 1K in series, 5·1V Zener
- 1 Analogue Output – 0-2·5V or 0-10V. 8 bit (20mV/step)
- 8 Digital Outputs – Open collector, 500mA, 33V max
- Custom box (140 x 110 x 35mm) with printed front & rear panels
- Windows software utilities (3·1 to XP) and programming examples
- Supply: 12V DC (Order Code PSU203)

Kit Order Code: 3093KT – **£64.95**
Assembled Order Code: AS3093 – **£94.95**

World Radio History

Hot New Kits This Summer!

Here are a few of the most recent kits added to our range. See website or join our email Newsletter for all the latest news.

NEW! EPE Ultrasonic Wind Speed Meter

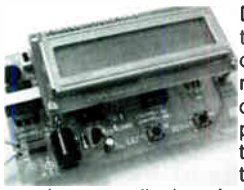
Solid-state design wind speed meter (anemometer) that uses ultrasonic techniques and has no moving parts and does not need calibrating. It is intended for sports-type activities, such as track events, sailing, hang-gliding, kites and model aircraft flying, to name but a few. It can even be used to monitor conditions in your garden. The probe is pointed in the direction from which the wind is blowing and the speed is displayed on an LCD display.

Specifications

- Units of display: metres per second, feet per second, kilometres per hour and miles per hour
- Resolution: Nearest tenth of a metre
- Range: Zero to 50mph approx.

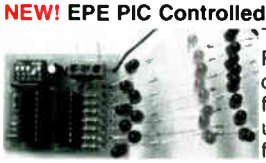
Based on the project published in Everyday Practical Electronics, Jan 2003. We have made a few minor design changes (see web site for full details). Power: 9VDC (PP3 battery or Order Code PSU345).
Main PCB: 50 x 83mm.
Kit Order Code: 3168KT – **£34.95**

NEW! Audio DTMF Decoder and Display



Detects DTMF tones via an on-board electret microphone or direct from the phone lines through the onboard audio transformer. The numbers are displayed on a 16-character, single line display as they are received. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC via the serial port. The unit will not detect numbers dialled using pulse dialling. Circuit is microcontroller based.
Supply: 9-12V DC (Order Code PSU345).
Main PCB: 55 x 95mm.
Kit Order Code: 3153KT – **£17.95**
Assembled Order Code: AS3153 – **£29.95**

NEW! EPE PIC Controlled LED Flasher



This versatile PIC-based LED or filament bulb flasher can be used to flash from 1 to 160 LEDs. The user arranges the LEDs in any pattern they wish. The kit comes with 8 superbright red LEDs and 8 green LEDs. Based on the Versatile PIC Flasher by Steve Challinor, *EPE* Magazine Dec '02. See website for full details. Board Supply: 9-12V DC. LED supply: 9-45V DC (depending on number of LED used). PCB: 43 x 54mm.
Kit Order Code: 3169KT – **£11.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix)

FM Bugs & Transmitters

Our extensive range goes from discreet surveillance bugs to powerful FM broadcast transmitters. Here are a few examples. All can be received on a standard FM radio and have adjustable transmitting frequency.

MMTX' Micro-Miniature 9V FM Room Bug

Our best selling bug! Good performance. Just 25 x 15mm. Sold to detective agencies worldwide. Small enough to hide just about anywhere. Operates at the 'less busy' top end of the commercial FM waveband and also up into the more private Air band.
Range: 500m. Supply: PP3 battery.
Kit Order Code: 3051KT – **£8.95**
Assembled Order Code: AS3051 – **£14.95**

HPTX' High Power FM Room Bug

Our most powerful room bug. Very Impressive performance. Clear and stable output signal thanks to the extra circuitry employed.
Range: 1000m @ 9V. Supply: 6-12V DC (9V PP3 battery clip suppied). 70 x 15mm.
Kit Order Code: 3032KT – **£9.95**
Assembled Order Code: AS3032 – **£17.95**

MTTX' Miniature Telephone Transmitter

Attach anywhere along phone line. Tune a radio into the signal and hear exactly what both parties are saying. Transmits only when phone is used. Clear, stable signal. Powered from phone line so completely maintenance free once installed. Requires no aerial wire – uses phone line as antenna. Suitable for any phone system worldwide. Range: 300m. 20 x 45mm.
Kit Order Code: 3016KT – **£7.95**
Assembled Order Code: AS3016 – **£13.95**

3 Watt FM Transmitter

Small, powerful FM transmitter. Audio preamp stage and three RF stages deliver 3 watts of RF power. Can be used with the electret microphone supplied or any line level audio source (e.g. CD or tape OUT, mixer, sound card, etc). Aerial can be an open dipole or Ground Plane. Ideal project for the novice wishing to get started in the fascinating world of FM broadcasting. 45 x 145mm.
Kit Order Code: 1028KT – **£23.95**
Assembled Order Code: AS1028 – **£31.95**

25 Watt FM Transmitter

Four transistor based stages with a Philips BLY89 (or equivalent) in the final stage. Delivers a mighty 25 Watts of RF power. Accepts any line level audio source (input sensitivity is adjustable). Antenna can be an open dipole, ground plane, 5/8, J, or YAGI configuration. Supply 12-14V DC, 5A. Supplied fully assembled and aligned – just connect the aerial, power and audio input. 70 x 220mm.
Order Code: AS1031 – **£134.95**

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Great introduction to the world of electronics. Ideal gift for budding electronics expert!

500-in-1 Electronic Project Lab

This is the top of the range and is a complete electronics course taking you from beginner to 'A' level standard and beyond! It contains all the parts and instructions to assemble 500 projects. You get three comprehensive course books (total 368 pages) – *Hardware Entry Course*, *Hardware Advanced Course* and a microcomputer based *Software Programming Course*. Each book has individual circuit explanations, schematic and assembly diagrams. Suitable for age 12 and above.
Order Code EPL500 – **£149.95**
30, 130, 200 and 300-in-1 project labs also available – see website for details.

Number 1 for Kits!

With over 300 projects in our range we are the UK's number 1 electronic kit specialist. Here are a few other kits from our range.

1046KT – 25W Stereo Car Booster £29.95
3087KT – 1W Stereo Amplifier £6.95
3105KT – 18W BTL mono Amplifier £9.95
3106KT – 50W Mono Hi-fi Amplifier £23.95
3143KT – 10W Stereo Amplifier £10.95
1011-12KT – Motorbike Alarm £12.95
1019KT – Car Alarm System £12.95
1048KT – Electronic Thermostat £9.95
1080KT – Liquid Level Sensor £6.95
3003KT – LED Dice £7.95
3006KT – LED Roulette Wheel £9.95
3074KT – 8-Ch PC Relay Board £24.95
3082KT – 2-Ch UHF Relay £30.95
3126KT – Sound-Activated Relay £8.95
3063KT – One Chip AM Radio £11.95
3102KT – 4-Ch Servo Motor Driver £15.95
3155KT – Stereo Tone Controls £11.95
1096KT – 3-30V, 5A Stabilised PSU £32.95
3029KT – Combination Lock £7.95
3049KT – Ultrasonic Detector £14.95
3130KT – Infra-red Security Beam £13.95
SG01MKT – Train Sounds £6.95
SG10 MKT – Animal Sounds £5.95
1131KT – Robot Voice Effect £9.95
3007KT – 3V FM Room Bug £6.95
3028KT – Voice-Activated FM Bug £11.95
3033KT – Telephone Recording Adpt £8.95
3112KT – PC Data Logger/Sampler £18.95
3118KT – 12-bit Data Acquisition Unit £49.95
3101KT – 20MHz Function Generator £69.95

No.1 FOR KITS

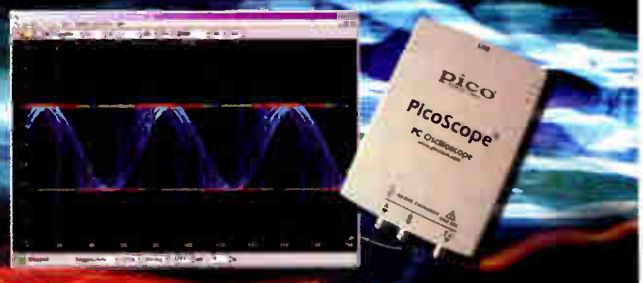
www.quasarelectronics.com

Secure Online Ordering Facilities ● Full Product Listing, Descriptions & Photos ● Kit Documentation & Software Downloads

World Radio History

PicoScope 3000 Series PC Oscilloscopes

The PicoScope 3000 series oscilloscopes are the latest offerings from the market leader in PC oscilloscopes combining high bandwidths with large buffer memories. Using the latest advances in electronics, the oscilloscopes connect to the USB port of any modern PC, making full use of the PCs' processing capabilities, large screens and familiar graphical user interfaces.



- High performance: 10GS/s sampling rate & 200MHz bandwidth
- 1MB buffer memory
- High speed USB 2.0 interface
- Advanced display & trigger modes
- Compact & portable
- Supplied with PicoScope & PicoLog software

PicoScope	3204	3205	3206
Bandwidth	50MHz	100MHz	200MHz
Sampling rate (repetitive)	2.5GS/s	5GS/s	10GS/s
Sampling rate (single shot)	50MS/s	100MS/s	200MS/s
Channels	2+Ext trigger	2+Ext trigger/Sig gen	2+Ext trigger/Sig gen
Oscilloscope timebases	5ns/div to 50s/div	2ns/div to 50s/div	1ns/div to 50s/div
Timebase accuracy	50ppm	50ppm	50ppm
Spectrum ranges	0 to 25MHz	0 to 50MHz	0 to 100MHz
Buffer memory size	256KB	512KB	1MB
Resolution / accuracy	8 bits / 3%		
Ranges	±100mV to ±20V		
PC Connection	USB2.0 (USB1.1 compatible)		

Tel: 01480 396395
www.picotech.com/scope221

pico Technology Limited

PLEASE ENSURE YOU TELEPHONE TO CHECK AVAILABILITY OF EQUIPMENT BEFORE ORDERING OR CALLING.

SPECIAL OFFERS

OSCILLOSCOPES

TEKTRONIX 2247A 4 Channel 100MHz Counter/Timer/ Voltmeter £275
TEKTRONIX 2335 Dual Trace 100MHz Delay Sweep £125
TEKTRONIX 485 Dual Trace 350MHz Delay Sweep £300
IWATSU SS5711 4 Channel 100MHz Delay Sweep £150
PHILIPS 3065 2+1 Channel 100MHz Dual TB/Delay – Autoset £200
PHILIPS 3055 2+1 Channel 60MHz Dual TB/Delay – Autoset £150
PHILIPS PM3217 Dual Trace 50MHz Delay Sweep £125
KIKUSUI COS6100 5 Trace 100MHz Delay £150
TEKTRONIX 475A Dual Trace 250MHz Delay Sweep £175
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep £150
TEKTRONIX 465B Dual Trace 100MHz Delay Sweep £125
TEKTRONIX 465 Dual Trace 100MHz Delay Sweep £95
PHILIPS PM3209 Dual Trace 40MHz Delay £125
PHILIPS PM3215 Dual Trace 50MHz £75
KENWOOD CS4035 Dual Trace 40MHz £50
PANASONIC VP5564A Dual Trace 40MHz £50
HITACHI V525 Dual Trace 50MHz Cusors £95
HITACHI V523 Dual Trace 50MHz Delay £80
HITACHI V425 Dual Trace 40MHz Cursors £75
HITACHI V422 Dual Trace 40MHz £60
HITACHI V223 Dual Trace 20MHz Delay £60
HITACHI V222 Dual Trace 20MHz £50
HITACHI V212 Dual Trace 20MHz £50
FARNELL DTV12-14 Dual Trace 12MHz £40

STORAGE

PHILIPS PM3320 Dual Trace 200MHz 250Ms/S £300
LECROY 9400 Dual Trace 125MHz £325
TEKTRONIX 468 Dual Trace 100MHz Delay Sweep Digital Storage £200
VELLEMAN HPS5 1MHz 5MHz Sampling Handheld Unused £60

ANALYSERS

ADVANTEST R3265A 100Hz-8GHz £4500
TEKTRONIX 492P 50kHz-21GHz £2250
HP8560A 50Hz-2.9GHz Built In Tracking Gen £3250
HP 8560A 50Hz-2.9GHz £2950
HP 8569A 10MHz-22GHz £950
HP 8565A 10MHz-22GHz £750
HP 853A with 8559A 100kHz-21GHz £1100
HP 182T with 8559A 100kHz-21GHz £750
HP182T with 8558B 100kHz-1500MHz £600
HP 182T with 8557A 10kHz-350MHz £300-£400
HP 140T with 8555A 10MHz-18GHz £500
ADVANTEST TR4131 10kHz-3.5GHz £950
WAYNE KERR SSA1000A 150kHz-1GHz £950
MARCONI 2382 20kHz-400MHz High Resolution £1250
MARCONI 2370 30Hz-110MHz £500
HP 8754A Network Analyser 4-1300MHz £500
MARCONI 6500A Amplitude Analyser with head £750
HP 334A Distortion Analyser 5Hz-600kHz £100

SIGNAL GENERATORS

HP 8350B Sweeper with 83592B 10MHz-20GHz £1500
HP 8350A Sweeper with 83592A 10MHz-20GHz £1250
HP 8350B Main Frame Only £125
HP 83525B RF Plug-in for 8350 0.01-8.4GHz £500
HP 83590A RF Plug-in for 8350 2-20GHz £800
HP 8660C Sig Gen 1.3GHz £450
HP 8660C Sig Gen 2.6GHz £750
HP 86603A RF Plug-in for 8660C 1-2600MHz £...
HP86631B Axillary Section for 8660C £...
HP86632B Modulation Section for 8660C £...
MARCONI 2017 0.01-124MHz Low Phase Noise £500
MARCONI 2019 Synthesised AM/FM 80kHz-1040MHz £325
FLUKE 6060B AM/FM Syn Sig Gen 10kHz-1050MHz £300
LEADER LSG221B Sig Gen 25-950MHz £200
HP 8656B Synthesised 0.1-990MHz £500
HP 8656A Synthesised 0.1-990MHz £400
HP 8640A AM/FM 500kHz-512MHz £150
HP 8620C Sweep Osc with 86290B 2-18.6GHz £500
HP8620C Sweep Osc with 86222B 0.01-2.4GHz £400
HP8620C/B/A with any of the following plug-ins £150-£200
HP 86220A Plug in 10-1300MHz
HP 86230B Plug in 1.5-4GHz
HP 86235A Plug in 1.7-4.3GHz
HP 86240A Plug in 2-8.5GHz
HP 86240C Plug in 3.6-8.6GHz
HP 86245A Plug in 5.9-12.4GHz
HP86250B Plug in 8-12.4GHz
HP 86250D Plug in 8-12.4GHz
HP 86260A Plug in 12.4-18GHz
MARCONI TF2015 AM/FM 10-520MHz £95
MARCONI TF2016 AM/FM 10kHz-120MHz £95
PHILIPS PM5328 100kHz-180MHz with .00MHz Freq Counter IEEE £225
PANASONIC VP8117A AM/FM 100kHz-110MHz FM 0-100kHz Digital Display etc Unused £225
HP 8165A Programmable Signal Source 1MHz-50MHz (Pulse/ Function) £325
HP 3325A Synthesised Function Gen 21MHz £350
HP 3312A Function Gen 0.1Hz-13MHz AM/FM Sweep/Trig/Burst etc £200
WAVETEK 21 Stabilised Function Gen 11MHz £225
WAVETEK 23 Synthesised Function Gen 12MHz £275
EXACT 529 AM/FM Function Gen 2MHz £150
ANALOGUE 2040 Synthesised Multi Function Waveform £250
THANDER TG503 Pulse/Function Gen 5MHz £195
THANDER TG502 Sweep/Function Gen 5MHz £195
KRON-HITE 5200A Sweep Func Gen 0.00003Hz-3MHz £150
HP 3310B Info as 3310A + etc £120
HP 3310A Func Gen 0.005Hz-5MHz Sine/Sq/Tri/Ramp/Pulse £80
PHILIPS PM5132 Function Gen 4.1Hz 2MHz £95
PHILIPS PM5131 Function Gen 4.1Hz 2MHz £75
FEEDBACK FG601 Func Gen 0.001Hz-1MHz £60
HP 8112A Pulse Gen 50MHz £750
HP 8111A Pulse Generator 20MHz £400
LYONS PG73N Pulse Gen 20MHz £50
LEADER LAG120B Sine/Sq Audio Generator 10Hz-1MHz £60
FARNELL LFM4 Sine/Sq Osc 1Hz-1MHz Low Distortion, TTL Output Amplitude Meter £60
GOULD J3B Sine/Sq Osc 10Hz-100kHz Low Distortion £50-£75
FARNELL LF1 Sine/Sq Oscillator 10Hz-1MHz £50
MARCONI SANDERS 6065C Signal Source 80-2000MHz £125
MARCONI SANDERS 6056B Signal Source 850-2150MHz £125
MARCONI SANDERS 6056B Signal Source 2-4GHz £125
MARCONI SANDERS 6057B Signal Source 4.5-8.5GHz £125
MARCONI SANDERS 6059A Signal Source 12-18GHz £125
MARCONI SANDERS 6070A Signal Source 400-1200MHz £125
FLUKE 6011A Synthesised 1MHz £125
PHILIPS 5514V Colour Bar Generator Video £195
BLACK STAR ORION Colour Bar Gen £...
BLACK STAR ORION Later Version Metal Case £75

FREQUENCY COUNTERS/TIMERS

EIP 371 Source Locking Microwave Counter 10Hz-18GHz £325
EIP 331 Autonet Microwave Counter 625MHz-18GHz £195
HP 5386A Counter 10Hz-12GHz £350
FEEDBACK SC230 Counter 1.3GHz £75
RACAL 9916 Counter 10Hz-520MHz £75
RACAL 9905 Universal Counter 200MHz £95
RACAL 9904 Counter Timer 50MHz £50
RACAL 1991 Counter/Timer 160MHz 9 digit £195
MARCONI 2431A Frequency Meter 200MHz £50
MARCONI 2437 Counter/Timer 1GHz £75
HP 5340A Automet Microwave Counter 10Hz 18GHz £250
HP 5316A Universal Counter 0-100MHz HPIB £95
THANDAR TF810 Frequency Counter 5Hz-200MHz Battery £60
THANDAR TF200 Frequency Meter 10Hz-200MHz 8 digit £40
BLACK STAR Meteor 100 Counter 5Hz-100MHz £50
BLACK STAR 1325 Counter Timer 1300MHz £150
BECKMAN UC10A Universal Counter 120MHz £60
LEADER LDC9043 Digital Counter 100MHz £125

DIGITAL MULTIMETERS ETC

SOLARTRON 7150 6½ digit True RMS IEEE £75
SOLARTRON 7150Plus ... Ability + Temp Measurement £100
DATRON 1065 5½ digit Autocal AC/DC Resistance IEEE £95
FLUKE 77 3½ digit Handheld £35
FLUKE 77 Series 2 3½ digit Handheld £45
FLUKE 8060A 4½ digit True RMS Handheld £75
BECKMAN HD110 3½ digit Handheld in Carry Case £30
TTI 1905A 5½ digit Bench £60
SOLARTRON 7045 4½ digit Bench £30
AVO DA116 3½ digit with Batteries & Leads £20
AVO 8 Mk6 in Ever Ready Case with Leads etc £75
AVO 8 Mk5 with Leads etc £50
RACAL 9301A True RMS RF Millivoltmeter £125
RACAL 9300 True RMS Millivoltmeter 5Hz-20MHz usable to 40MHz £30
RACAL 9300B as 9300 £45
GOODWILL GVT427 Dual Chan AC Millivoltmeter 10mV in 12 ranges 10Hz-1MHz Unused £75
KENWOOD VT176 Dual Chan Millivoltmeter £40

POWER SUPPLIES

FARNELL XA35.2T 0-35V 0-2A Twice Digital £95
FARNELL LT30-2 0-30V 0-2A Twice £110
FARNELL B30/20 30V 20A Variable No Meters £110
FARNELL B30/10 30V 10A Variable No Meters £55
FARNELL LT30-1 0-30V 0-1A Twice £75
FARNELL L30.2 0-30V 0-2A £55
FARNELL L30.1 0-30V 0-1A £40
FARNELL E350 0-350V 0-200mA £125
FARNELL D30-2T 0-30V 0-2A Twice Digital £95
THURLBY PL330 0-32V 0-3A Digital (Kenwood badged) £75
THURLBY TS3021S 0-30V 0-2A LCD £65
THURLBY PL320 0-30V 0-2A Digital £55
TAKASAGO GMO35-3 0-35V 0-3A 2 Meters £45
TAKASAGO TMO35-2 0-35V 0-2A 2 Meters £35
ISOLATING TRANSFORMER - Yellow - 500VA with 13Amp Socket £35

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17A King Street, Mortimer, Near Reading RG7 3RS
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VISA

Used Equipment – GUARANTEED. Manuals supplied
This is a VERY SMALL SAMPLE OF STOCK. SAE or Telephone for lists.
Please check availability before ordering.
CARRIAGE all units £16. VAT to be added to Total of Goods and Carriage

World Radio History

EPE PROJECT PICs

Programmed PICs for EPE Projects
12C508/9-£3.90; 16F627/8 - £4.90
16F84/71/ - £5.90
16F876/877/ 18Fxxxx - £10.00
All inc. VAT and Postage

1kV/500V Insulation Tester

Super design. Regulated output and efficient circuit. Dual scale meter, compact case. Reads up to 200 Megohms.
Kit includes wound ferrite transformer, drilled and punched case, meter scale, PCB & ALL components. (Needs PP3 battery).

KIT 848...£32.95

DUAL OUTPUT *TENS* UNIT

An excellent kit for this project based on the EPE March'97 Design. Our Full Kit includes all components, hardware and an improved Magenta pcb. All hardware and electrodes are included. Designed for simple assembly and testing, providing a high level controlled dual output drive.

KIT 866 .. £32.90
Inc. 4 electrodes

Set of 4 Spare Electrodes £6.50

EPE MICROCHIP P.I. Treasure Hunter

Stable Sensitive Pulse Induction detector. Easy to build and use. No ground effect - works in sea water. Detects Gold Silver, ferrous and non ferrous metals.

KIT 847 ... £63.95

Kit includes Headphones, coil and all Hardware

Ultrasonic PEsT Scarers

Two Ultrasonic PEsT Scarers. Kit 812 produces regular high level pulses of 32kHz. Kit 867 produces Random pulses and can work with an optional slave unit to give two separate ultrasound sources. Both kits need 9V supply.

Kit 812 ... £14.81 psu . 3.99
Kit 867 ... £19.99 867Slave £12.51

MOSFET MKII Bench PSU 0-25V 2.5A

Based on Mk1 design, with switching pre-regulator for high efficiency. Panel meters for A and V. Toroidal transformer. Variable Volts 0 - 25 AND Variable Current limit from 0 -2.5A
Kit includes punched and labelled case. A classic and essential piece of test gear

Kit 845 ... £64.95

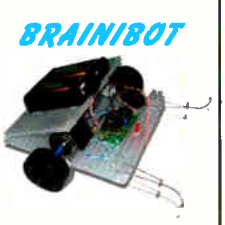
68000 Trainer Kit 621.. 99.95

Stepping & DC Motors

A range of motors for many applications:
Visit our website for more details
MD100 100 step Unipolar..... £9.99
MD200 200 step Unipolar..... £12.99
MD24 Type '23' size 200 step..£22.95

MAGENTA BRAINIBOT I & II

- Full kit with ALL hardware and electronics.
- As featured in *EPE* Feb '03 (KIT 910)
- Seeks light, beeps, and avoids obstacles
- Spins and reverses when 'cornered"
- Uses 8 pin PIC chip
- ALSO KIT 911 - As 910 *PLUS* programmable from PC serial port leads and software CD included.

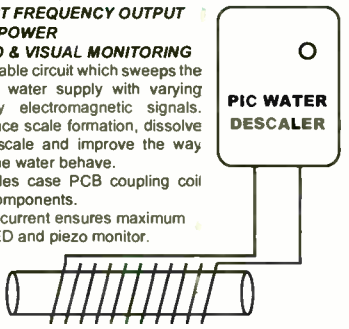


KIT910..£16.99
KIT911..£24.99

PIC PIPE DESCALER

- *SIMPLE TO BUILD*
- *SWEPT FREQUENCY OUTPUT*
- *HIGH POWER*
- *AUDIO & VISUAL MONITORING*

An affordable circuit which sweeps the incoming water supply with varying frequency electromagnetic signals. May reduce scale formation, dissolve existing scale and improve the way salts in the water behave.
Kit includes case PCB coupling coil and all components.
High coil current ensures maximum effect. LED and piezo monitor.



KIT 868 .. £22.95 PSU £3.99

12V EPROM ERASER

A safe low cost eraser for up to 4 EPROMS or other UV erasable windowed devices at a time in 20 minutes. Operates from a 12 Volt supply (400mA). Ideal for mobile work -and in educational applications where mains voltages are to be avoided. Safety interlock prevents contact with UV.

KIT 790 ..... £29.90

PIC LCD DISPLAY DRIVER

16 Character x 2 Line display, pcb, programmed PIC16F84, software disk and all components to experiment with standard intelligent alphanumeric displays. Includes full PIC source code which can be changed to match your application.

- Learn how to drive the display and write your own code.
- Idea development base for meters, calculators, counters, timers --- just waiting for your application
- **Top quality display** with industry standard driver, data and instructions

KIT 860.£19.99

PIC STEPPING MOTOR DRIVER

PCB with components and PIC16F84 programmed with demonstration software to drive any 4 phase unipolar motor up to 24 Volts at 1 Amp. Kit includes 100 Step Hybrid Stepping Motor Full software source code supplied on disc. Use this project to develop your own applications. PCB allows 'simple PIC programmer' 'SEND' software to be used to reprogram chip.

KIT 863.....£18.99

8 CHANNEL DATA LOGGER

From Aug/Sept.'99 *EPE*. Featuring 8 analogue inputs and serial data transfer to PC. Magenta redesigned PCB - LCD plugs directly onto board. Use as Data Logger or as a test bed for developing other PIC16F877 projects. Kit includes lcd, programmed chip, PCB, Case, all parts and 8 x 256k EEPROMs

KIT 877.....£49.95

SUPER PIC PROGRAMMER

Magenta's original parallel port programmer. Runs with downloaded WINDOWS 95 - XP software. Use standard Microchip .HEX files. Read/Prog/Verify wide range of 18,28,and 40 pin PICs. Including 16F84/876/877, 627/8, (Inc. 'A' versions) + 16xx OTPs.

KIT 862. £29.99 Power Supply £3.99

ICEBREAKER

PIC Real Time
In-Circuit Emulator

With serial lead & software disk, PCB, Breadboard, PIC16F877, LCD, all components and patch leads.

KIT 900..£34.99 PSU £3.99

- Featured in *EPE* Mar'00
- Ideal for beginners & experienced users. Windows (95 to XP) Software included

ICEbreaker uses PIC16F877 in-circuit debugger functions.

20W Stereo Amp.

EPE May '05 -- Magenta Stereo/Mono Module

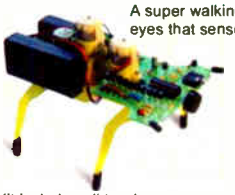
Wide band Low distortion 11W / channel Stereo 20W Mono. True (rms) Real Power

Short Circuit & Overheat Protected. Needs 8 to 18V supply.

Latest Technology - Stable, Reliable, high performance IC with local feedback.

KIT 914 ..... £11.90
(includes all parts & heatsink for stereo or mono)

Magenta BrainiBorg



A super walking programmable robot with eyes that sense obstacles and daylight.
BrainiBorg comes with PC software CD *(WIN95+ & XP)* with illustrated construction details, and can be programmed to walk and respond to light and obstacles on any smooth surface.
Kit includes all hardware, components, & 3 motor/gearboxes. Uses 4 AA batteries *(not supplied)*.

KIT 912 ... £29.99 *(Kit with CD Rom & Serial Lead)*
KIT 913 ... £38.95 *(As 912 but Built & Tested Circuit board)*

EPE PIC Toolkit 3

As in EPE Apr/May/Jun '03 and on PIC Resources CD

- **Magenta Designed Toolkit 3 board with printed component layout, green solder mask, places for 8,18, 28 (wide and slim), and 40 pin PICs. and many Magenta extras. Also runs with WinPic800 prog. Software.**
- **16 x 2 LCD, PIC chip all parts and sockets included.**
- **Follow John Becker's excellent 'PIC tutorial 2' series.**

KIT 880 ... £34.99 *(With 16F84 Chip)*
KIT 880 ... £39.99 *(With 16F877 Chip)*

OR - Built & Tested £49.99 & £55.99

EPE TEACH-IN 2004

COMPLETE 12 PART SERIES FROM NOV03 All parts to follow this Educational Electronics Course. Inc. Breadboard, and wire, as listed on p752 Nov 03'

KIT920..£29.99

Additional Parts as listed in 'misc.' Section *(less RF modules, Lock, and Motor/g.box)*

KIT921.£12.99

Reprints £1.00 per part.

BAT DETECTORS

Magenta's Super Heterodyne Bat detectors. Our best selling kit 861 now includes a drilled case and front panel label. The MkIIb and digital MkIII are supplied built & ready to go

KIT 861 .. £37.99 *Soft Zip Up Pouch for all 3....£5.99*
MkIIb .. £49.95 **MkIII .. £89.95**

All Prices Include VAT, Add £3.00 P&P per order, or £7.99 for next day.
Chqs. P.O. & Most major cards accepted.
See our Website for many more kits, products, & Secure On Line ordering.
Mail Order Only.

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World Radio History

PCB Production - Development

0.1" Copper Stripboard

Size	Tracks/Hales	
25 x 64mm	9T / 25H	£0.24
64 x 95mm	24T / 37H	£0.87
95 x 127mm	36T / 50H	£1.41
95 x 432mm	36T / 170H	£4.39
100 x 100mm	39T / 38H	£1.40
100 x 500mm	39T / 199H	£6.20
119 x 455mm	46T / 179H	£5.40
Stripboard track cutter		£1.99

Solderless Breadboard

Tie Points & Size	Power Rails	
390 81 x 60mm	2	£2.75
840 175 x 67mm	2	£4.86
740 175 x 55mm	1	£4.03
640 175 x 42mm	0	£3.08

Many other sizes available, also jump wires & matrix board.

PCB Production - Drafting Materials

A4 Artwork Film (per 10 sheets)

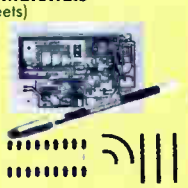
Clear Manual Film	£1.20
Clear Laser Film	£1.75
White HQ Laser Film	£4.62

Etch Resist Pens

"Dala" Pen	£2.98
"Staedtler" Fine Pen	£0.88

Etch Resist Transfers

Sena mixed DIL pads	£2.24
Sena mixed Rnd pads	£2.24
Alfac mixed pads	£1.84
Transfer Spatular	£1.25



We carry the full range of Sena & Alfac PCB transfers, see our catalogue for full details.

Soldering Irons

We carry in stock a wide range of soldering iron and soldering accessories. Irons from 12 to 100 Watts.

20W 240V Basic	£3.74
25W 240V Ceramic	£7.14
30W 240V Basic	£4.68

Desolder Pumps

Basic 165 x 18mmØ	£2.85
Antistatic 195mm	£3.92
Antex Mini 198mm	£6.02
Antex Pro 210mm	£10.26

Soldering Station

A 48W adjustable temperature soldering station with a rotary dial, LED Temperature metering, on-off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 420 C, Low voltage iron with Silicane cable.
Supply: 240V, Iron: 24V 48W

Model 167-540 £49.00

Soldering Station

A 48W adjustable temperature soldering station with a rotary dial, Digital Temperature Indication, on-off switch, iron holder and tip cleaning sponge. This station features accurate heat sensing for instant compensation & stable temperatures. Adjustable temperature range of 150 - 480 C, Low voltage iron with Silicane cable.
Supply: 240V, Iron: 24V 48W

Model 167-570 £64.40

Digital Multimeter

Model: 121-120
Price: £11.47

A highly featured digital multitester for professional use. Offers 30 ranges and 8 functions including temperature, capacitance, diode, continuity and hFE measurement. Large 3.5 digit LCD display with automatic polarity indicator. Supplied with shrauded test leads, K type temperature probe and shock proof rubber holster.

Technical Specifications

DC voltage 200mV - 1000V (±0.5%)
AC volts 2V - 700V (±0.8%)
DC current 2mA - 20A (±1.2%)
AC current 200mA - 20A (±1.8%)
Resistance 200 Ohms - 20M Ohms (±0.8%)
Capacitance 2000pF - 20μF (±2.5%)
Temperature 0 C - 1000 C (±1.5%)
Frequency 20kHz (±1%)
Max display 1999
Power supply 9V (PP3 battery)
Dimensions 88 x 173 x 40 mm

Now available online
Our large range of Tools by
C.K A friend for life
DRAPER
JOKARI

PCB Production - Processing Equipment

We carry a large range of the photographic & chemical processing equipment for PCB production, a full list with full technical specifications is available in our catalogue or visit our web site.

UV Exposure units

2 x 8W Tubes, 6 min timer
229 x 159mm working area
Model 332-002 £98.75
4 x 15W Tubes, 7½ min timer
330 x 260mm working area
Model 332-004 £209.48

Chemical Processing

Law cost plastic tray £1.80
Process tanks feature electrically operated pumps and/or heaters with thermostat control, suitable for boards upto 320 x 260mm.
Universal Tank with heater
Model 333-007 £169.58
Bubble etch Tank with heater & bubble pump.
Model 333-004 £208.48

Any of these items, carriage £5.50

PCB Production - Tools

Drill Bits

HSS parallel shank bits available in sizes from 0.3mm to 2.0mm

0.3-0.95mm in 0.05mm steps	£0.60ea £4.00/10
1.0-2.0mm in 0.1mm steps	£0.40ea £3.60/10

HSS Reduced shank (2.35mm) bit available in sizes from 0.6mm to 1.7mm in 0.1mm steps £0.84ea £7.60/10

Regraund Tungsten carbide reduced shank available in sizes from 0.6 to 1.6mm in 0.1mm steps £1.90

Drilling Machines

Expa Reliant 12V drill, 3.8mm capacity, 8400rpm £12.78
Expa Zircan 12V drill, 3.8mm capacity, 11900rpm £14.20

Minicraft MX1 230V, 8000 - 21000rpm with chuck & collet. Model EPE270-390
Normal price £48.51

SPECIAL PRICE £31.02

Servisol Products

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Range	Int Ω
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0-1mA	200Ω
0-10mA	2Ω6
0-50mA	1Ω2
0-100mA	0Ω65
0-1A	60mΩ
0-3A	20mΩ
0-5A	12mΩ
0-15A	4mΩ
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100 x 220mm Single	£1.49
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220 x 100mm			£3.08	£3.71
233 x 160mm			£4.83	£5.32
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100ml	Aerasal Phataresist spray, cavers 2m²	£4.25
50g	Pawder develaper, makes 1lt	£1.09
500g	Pawder develaper, makes 10lt	£7.08
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26 Way	£0.26	£13.94
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World Radio History

EVERYDAY PRACTICAL ELECTRONICS

THE UK's No.1 MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

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Popular

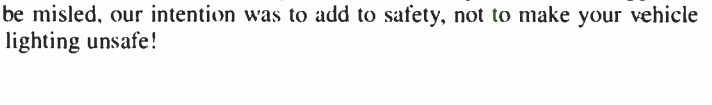
The new format and style *EPE* has proved to be very popular, with many readers being unable to get copies of the first two redesigned issues. Both Jan. and Feb. '06 issues have now completely sold out and we can no longer supply back issues, only reprints of articles. That popularity also shows through in the projects we publish, in particular those for cars and music – with the *Speed Camera Watch MK2* (Nov. '05) being the most popular project we have published in recent years, closely followed by the other car projects and by music related designs.

Last month's *LED Lighting For Your Car* projects have attracted much attention but we must point out that these should not be used to replace normal car stop, side or indicator lamps, they were not designed for that purpose. As discussed in the article most L.e.d.s. have a very narrow emission angle and the designs are not suitable (indeed are illegal) to use as replacements for conventional tail, stop and indicator lamps. Uses were suggested so please don't be misled, our intention was to add to safety, not to make your vehicle illegal and your lighting unsafe!

More

No doubt this issue will also prove popular, with the eagerly awaited *Widgy Box* and our *Digital Instruments For Cars* projects, but please don't feel these are the only areas we cover, next month there is a *PC Infra Red Remote Receiver*, John Becker's PIC-based *Sudoku Unit* plus a *Dirt Cheap High Current Bench Supply* design – something for everyone.

In order not to miss out – like some have already – please place an order with your newsagent or take out a subscription – see pages 67 and 69.



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We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.**

PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.
We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT

We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

AVAILABILITY

Copies of *EPE* are available on subscription anywhere in the world (see opposite), from all UK newsagents (distributed by SEYMOUR) and from the following electronic component retailers: Omni Electronics and Yebo Electronics (S. Africa). *EPE* can also be purchased from retail magazine outlets around the world. An Internet on-line version can be purchased and downloaded for just $15.99US (approx £9.50) per year available from **www.epemag.com**

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World Radio History

News . . .

A roundup of the latest Everyday News from the world of electronics

REPAIRING BROKEN CSS

DVD Encryption Security Has Been Hacked – By A Schoolboy! Barry Fox reports

BRAD Hunt, Chief Technical Officer of the Motion Picture Association of America – which speaks for Hollywood – admitted to the International Recording Media Association conference in California recently that "CSS is broken". CSS is, of course, the encryption system used to stop people making digital copies of DVDs. But it was quickly hacked by a schoolboy and his DeCSS program is widely used to let legitimate copy programs make illegitimate copies of DVDs.

"There's work going on in this area", Hunt said, but would give no details on how the MPAA hopes to fix broken CSS. The encryption cannot be changed without making future discs unplayable on existing DVD players – which is the reason why the Advanced Access Content System built into both new blue laser systems (Blu-ray and HD-DVD) uses renewable keys for discs and players. A recent patent filed round the world by Bradley Thomas Collar of Warner Bros gives one clue to what the MPAA may have in mind (WO 2005/098832). The patent exploits the technical trick used by some deCSS copy programs to justify the legal argument that owners of DVDs should be able to make one digital clone copy, just as the SCMS system used to protect CDs permits one digital copy.

"The reasoning (albeit a flawed one) is that one archival copy should be allowed, but not rampant copying", says the patent. The DVD archive copy programs (like the now deceased DVD X-Copy and many others that have crept onto the market) put a file on the copy disc that identifies it as an "archive" copy. The program then looks for this file whenever it is asked to make a copy. If there is no archive file, the copy is made; if there is an archive file, no copy is made.

Warner is patenting the idea of putting an archive file on original discs. So any copy software that argues legality by refusing to copy a copy, will also refuse to copy an original disc. Another recent patent (US 20050232612), this time from Disney, claims the idea of putting many different trailers and promotional adverts on a DVD, along with "random" or "shuffle play" software. So a few of the promos play every time the disc is played, but they are different each time, or in different order.

The idea seems sensible. But what makes the patent especially interesting is the way it is worded. Referring to the current situation where tapes and discs contain a few promos that insist on playing every time you want to watch the movie, Disney's patent admits: "You must endure the same previews every time you play the movie, or be forced to "fast forward" through the previews to reach the actual movie ... (this) detracts from the enjoyment ... becomes annoying and has a detrimental effect on the viewer."

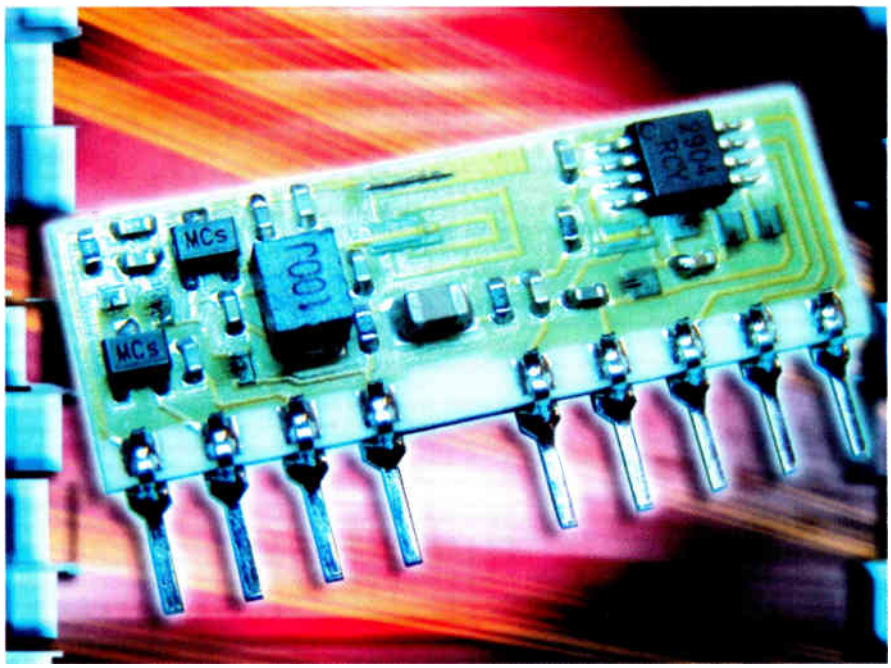
Miniature AM Receiver Module

The new AM-HRR30 "super-regen" AM receiver module from RF Solutions has a compact hybrid construction and is approximately half the size of other hybrid modules on the market. With overall dimensions of just 25·4mm × 8·9mm × 4mm, the AM-HRR30 can be easily integrated into customer applications. Its robust electrical and mechanical construction makes it especially useful in portable devices and other small form factor pieces of equipment.

The AM-HRR30 is able to capture undecoded data from any AM transmitter (for example RF Solutions' AM-RT4/5 range). The module has a receiving range of up to 50 metres and a data rate of up to 4800 bits/sec. The new devices can be supplied with operating frequencies between 300MHz and 450MHz. Standard parts are available with frequencies of either 315MHz or 433MHz.

Supply current for the AM-HRR30 is 3mA maximum. For applications where ultra-low power consumption is of paramount importance, RF Solutions offers the AM-HRR60 which draws a supply current of just 0·5mA.

The new modules specify very high frequency stability over their wide –25°C to +80°C operating temperature range. The durable construction of the AM-HRR30 ensures that its performance is maintained even in applications where it is subjected to mechanical vibration and manual handling. A unique patented laser trimming process gives a highly accurate on-board inductor that conveniently alleviates the need for any adjustable components in the design.



The ETSI300-220 compliant AM-HRR30 features a CMOS/TTL compatible output and requires no radio licence to operate. The only connections required are to an antenna and a 5V power supply.

Further information, contact: R.F. Solutions, Dept EPE, Unit 21, Cliffe Ind. Estate, South Street Lewes, East Sussex, BN8 6JL. Tel: +44 (0) 1273 898000. Fax: +44 (0) 1273 480661. Web:**www.rfsolutions.co.uk.** Email: sales@rfsolutions.co.uk.

World Radio History

Marconi Exhibition

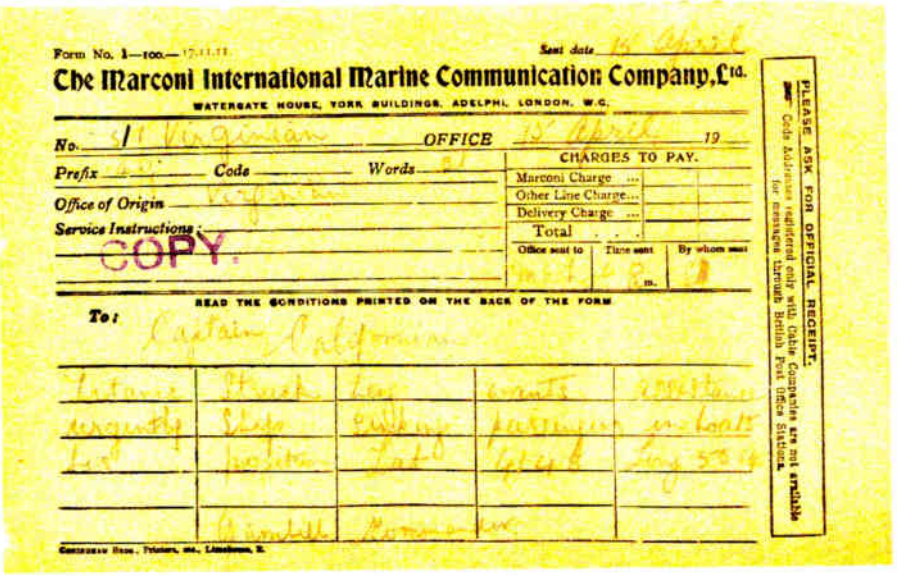
A special exhibition at the Museum of the History of Science is being held to mark the acquisition by the Museum and the Bodleian Library of the extraordinary Marconi Collection. The exhibition covers the history of radio from Marconi's early demonstrations in the 1890s to the beginning of regular public broadcasting in the 1920s.

This is the story of a technology that has shaped the modern world. At first, the major purpose for "wireless" seemed to be for sending individual messages in Morse code, with much greater flexibility than the established telegraph system, which relied on connections by wires. "Wire-less" would have military applications and would be especially valuable for communications at sea. However, there was nothing to stop people "listening in" and, with the coming of voice messages, enthusiasm grew for a completely different concept in communication – broadcasting.

The exhibition concentrates on the dramatic and memorable events in the early story:

- Marconi's celebrated early demonstrations, including cross-Channel signals
- The achievement of a trans-Atlantic signal in December 1901
- The *Titanic* disater and the use of radio to rescue survivors
- The development of radio in World War One
- The birth of broadcasting, up to the foundation of the BBC

These are illustrated by original instruments and documents of outstanding interest, including:



- Apparatus from Marconi's very first demonstrations, including the trans-Atlantic signal
- Famous original experimental notebooks and patents
- "Marconigram" messages sent from the *Titanic* and between ships in the vicinity (see above) after the fatal collision; this material has not been displayed before and is of great public interest
- Early radios and broadcast equipment, including the microphone used in Dame Nellie Melba's celebrated recital on 15 June 1920, the first live public entertainment broadcast.

The exhibition was opened on 24 April by Lord Patten of Barnes, Chancellor of the University of Oxford, and Princess Elettra Marconi, daughter of Guglielmo Marconi.

The exhibition dates are 25 April to 1 October 2006, Tuesday to Saturday 12pm to 4pm, Sunday 2pm to 5pm, admission free. There is also a range of special events.

For further information, please contact Dr Jim Bennett, tel: 01805 277281 (or 277280), email: jim.bennett@mhs.ox.ac.uk.

The Museum's website is at: **www.mhs.ox.ac.uk**.

PIXAR EXHIBITION

The Science Museum has opened a new exhibition examining the work of Pixar Animation Studios' artists, bringing together 250 drawings and paintings, 50 sculptures plus computer generated multimedia artworks. All of these works demonstrate the rich creativity behind the development of the studio's technologically advanced films.

Pixar: 20 Years of Animation, opened on 1 April 2006 and provides artistic and technological insight into the studio's hugely successful movies, ranging from *Toy Story, A Bug's Life, Toy Story 2, Monsters, Inc., Finding Nemo, The Incredibles* and the forthcoming Disney presentation of the Pixar film *Cars*, each of which are revolutionary films in animation.

To accompany the exhibition, the Museum will run a series of events for a range of audiences, from workshops for seven to 14 year olds, to talks with animators, directors, producers, Oscar winners and nominees, revealing the details and secrets of their work. Jon Tucker, Head of the Science Museum said:

"This exhibition will give our visitors a unique glimpse into Pixar Animation Studios, one of the most creative film studios in the world".

The exhibition will also look at the history of animation in film, using objects from the Science Museum's collection, including original Victorian magic lanterns, zoetropes, cameras and early pieces of animated film.

The exhibition has an exclusive 10-week run at the Science Museum until 10 June 2006. Admission: adult £9; child/student £7; Educational groups £4 per person; family: 2 adults + 1 child £20; 2 adults + 2 children £27. Exhibition tickets can be pre-booked on 0870 870 4868 or via the museum website.

Further information on the exhibition and all accompanying events can be found at **www.sciencemuseum.org.uk/pixar**.

Radio-Electronics Website

Ian Poole, author of our earlier *New Technology Update* column, tells us that his website **www.radio-electronics.com** now serves over 200,000 pages a month and is continuing to grow. Coupled with this, the site had over 60,000 visitors, proving its popularity. The site, which is run and edited by Ian, of Adrio Communications Ltd, aims to provide concise, useful overviews and tutorials in an easy to read form.

The website now has well over 300 pages of full content, making it one of the largest on the Internet and a significant resource of useful information. It covers a wide range of radio and electronics topics ranging from receiver technology and phase-locked loops, through antennas, feeders, circuits and components to the latest technologies including cellular telecommunications, Wi-Fi, Bluetooth, UWB and more. There are also some pages of interest covering radio and electronics history.

The site has been in existence for several years and over this time many positive comments have been received from a variety of users.

RAPID'S NEW PRODUCTS

We have received the latest edition of Rapid Electronics' *New Products Focus* publication. This is devoted to Rapid's new products, but it now also incorporates Rapid's *Focus* magazine. As such it also has a variety of feature articles of general interest, as well as product information.

Rapid are one of the industry's leading components distributors, and no hobbyist workshop should be without a copy of their main catalogue, of which the 2006 edition is now available.

For more information, contact Rapid Electronics Ltd., Dept EPE, Severalls Lane, Colchester, Essex CO4 5JS. Tel: 01206 751166. Fax: 01206 751188. Email: sales@rapidelect.co.uk. Web: **www.rapidelectronics.co.uk**.

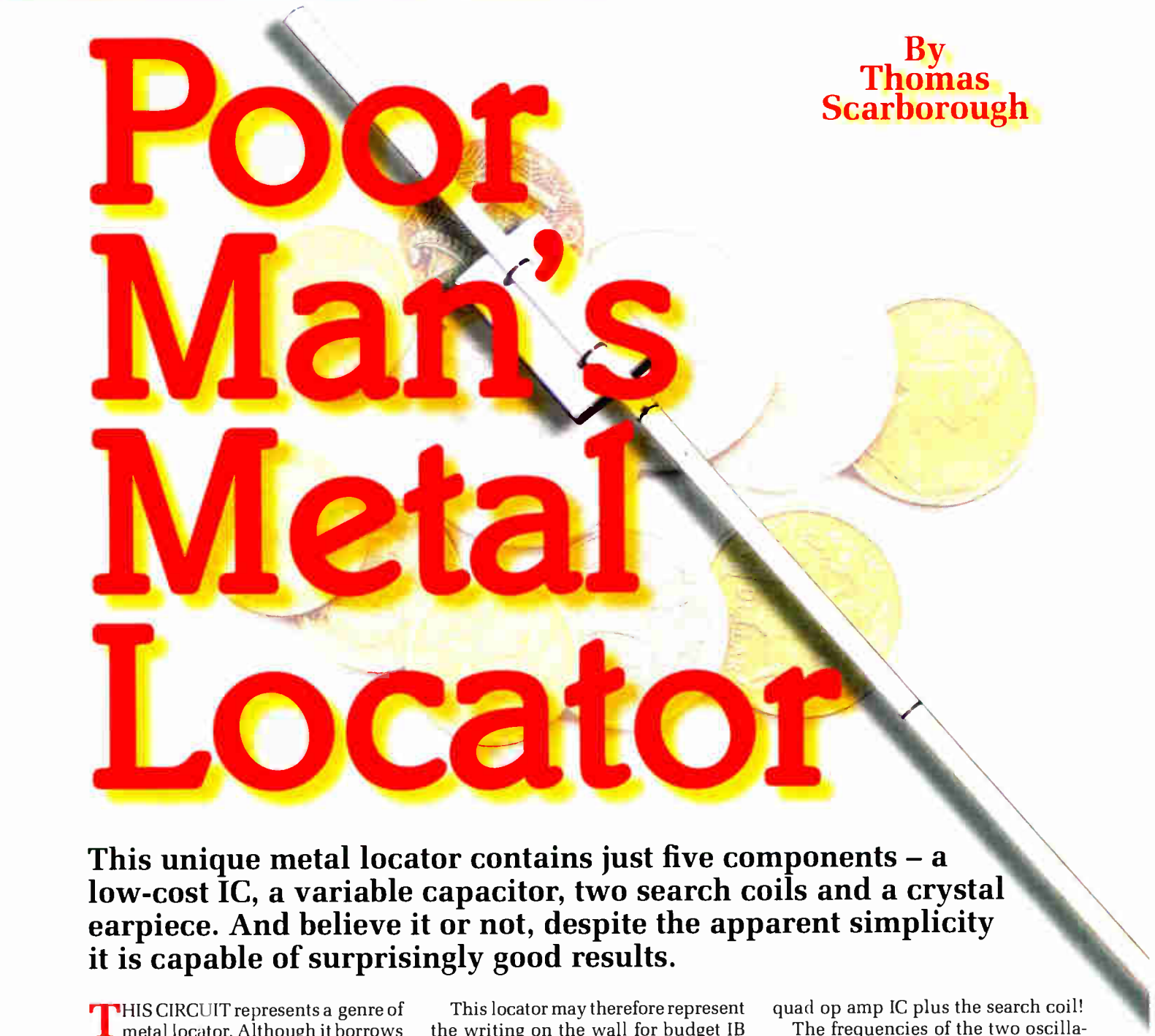
EOCS Magazine

The April '06 issue of the *Electronic Organ Magazine* has been received from the Electronic Organ Constructors Society (EOCS). If you are interested in electronic organs and such, contact: Treasurer EOCS, Dept EPE, 2 Boxhill Nurseries, Tadworth, Surrey KT20 7JF. Email: Treasurer@eocs.org.uk. Web: **www.eocs.org.uk**.

World Radio History

Poor Man's Metal Locator

By Thomas Scarborough



This unique metal locator contains just five components – a low-cost IC, a variable capacitor, two search coils and a crystal earpiece. And believe it or not, despite the apparent simplicity it is capable of surprisingly good results.

THIS CIRCUIT represents a genre of metal locator. Although it borrows from other kinds of locators/detectors, its basic principle of operation is different.

And while this may seem to stretch one's credulity, the performance matches that of a budget Induction Balance (IB) detector. Build it – and you will see! This design is even more simple than the original Beat Balance design published previously (*EPE* May 2004).

During testing, it detected an old English penny at 150mm (6") in air. However, I would only put my neck on the block for 125mm (5"), since a number of factors influence sensitivity.

This locator may therefore represent the writing on the wall for budget IB types and even puts paid to most of the advantages (the few remaining ones) of Beat Frequency Operation (BFO) detectors.

Overview

Instead of using a search and a reference oscillator (as in the BFO type), or transmit and receive coils (as in IB), this detector uses two transmitters (or search oscillators) with IB-style coil overlap.

As will be seen from Fig.1 and our photographs, these are extremely simple in design. Each oscillator comprises just one-quarter of a common quad op amp IC plus the search coil!

The frequencies of the two oscillators are then mixed (in similar fashion to a BFO) to produce an audible heterodyne.

On the surface of it, this design would seem to represent little more than a twinned BFO metal locator. However, what makes it different above all else (and significantly increases its range) is that each coil modifies the frequency of the adjacent oscillator through inductive coupling. This introduces the "balance" that is present in an IB metal locator and boosts sensitivity well beyond that of a BFO.

Beyond this, all that is required is a means to control the mixer output

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frequency, so that the metal locator can be tuned. This could be accomplished in a number of ways but the method chosen here is a variable capacitor (a standard 100pF AM radio tuner) wired between the two oscillator outputs.

Since the concept borrows from both BFO and IB, we give a nod to each of these by calling the principle "Beat Balance".

Characteristics

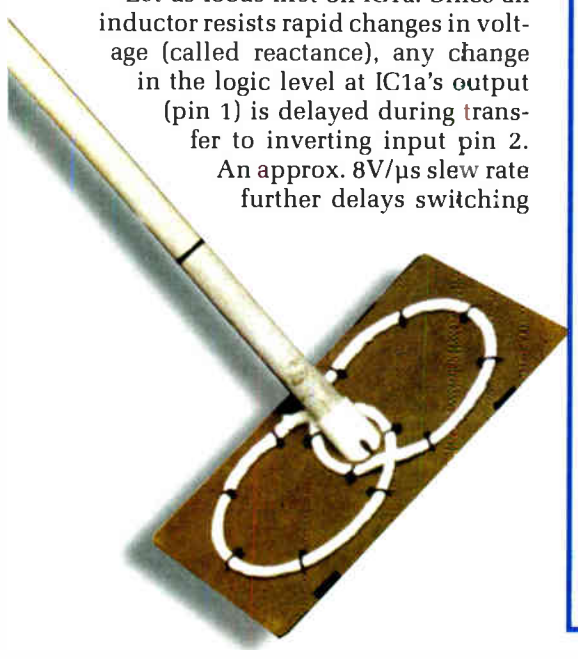
The main characteristics of beat balance (BB) are as follows:

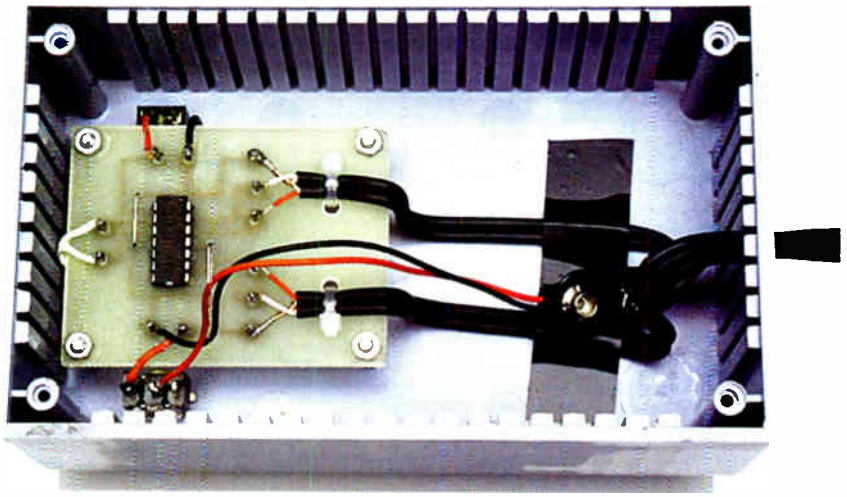
- Depending on the way it is designed, a BB metal locator potentially offers the same sensitivity as IB.
- It requires no receiver amplifier or level detector, thus vastly simplifying design and reducing cost. The present circuit uses just two main components, while matching the performance of a budget IB metal locator (which would probably have 10-20 parts).
- Both search oscillators are identical, therefore BB offers high immunity to voltage and temperature variations. This obviates the need for compensation circuits, including voltage regulation.
- Each search coil has the opposite response to metal, thus BB has a high degree of immunity to ground mineralisation. At the same time, it offers good discrimination at the point where the two search coils overlap

The circuit

The design is based on the simplest of inverter oscillators.

Let us focus first on IC1a. Since an inductor resists rapid changes in voltage (called reactance), any change in the logic level at IC1a's output (pin 1) is delayed during transfer to inverting input pin 2. An approx. 8V/µs slew rate further delays switching of IC1a, thus setting up a rapid oscillation.





This view inside the box shows the WHOLE circuit (with the exception of the coils, of course, and the tuning capacitor hidden under the PC board).

One end of the search coil is further wired to the non-inverting input (pin 3), which stabilises operation. While pin 3 could be left "floating", this would be a less satisfactory arrangement.

Since different ICs have different slew rates, as well as different input impedances, they are unlikely to work in this circuit. However, the TL074CN IC is widely available and there should be no sourcing problems.

The search coil is a critical part of the oscillator and needs to be suitably designed to achieve oscillation and to obtain the required frequency.

While this frequency needs to be high, it should not be so high that noise or instability are introduced. Both the characteristics of IC1 and the inductance of the coil influence oscillator frequency, which lies around 260kHz without a Faraday shield. The Faraday shield approximately doubles the inductance of the coil, thus roughly halving the frequency.

IC1b is wired in exactly the same way as IC1a, except that its search coil is connected in opposite phase.

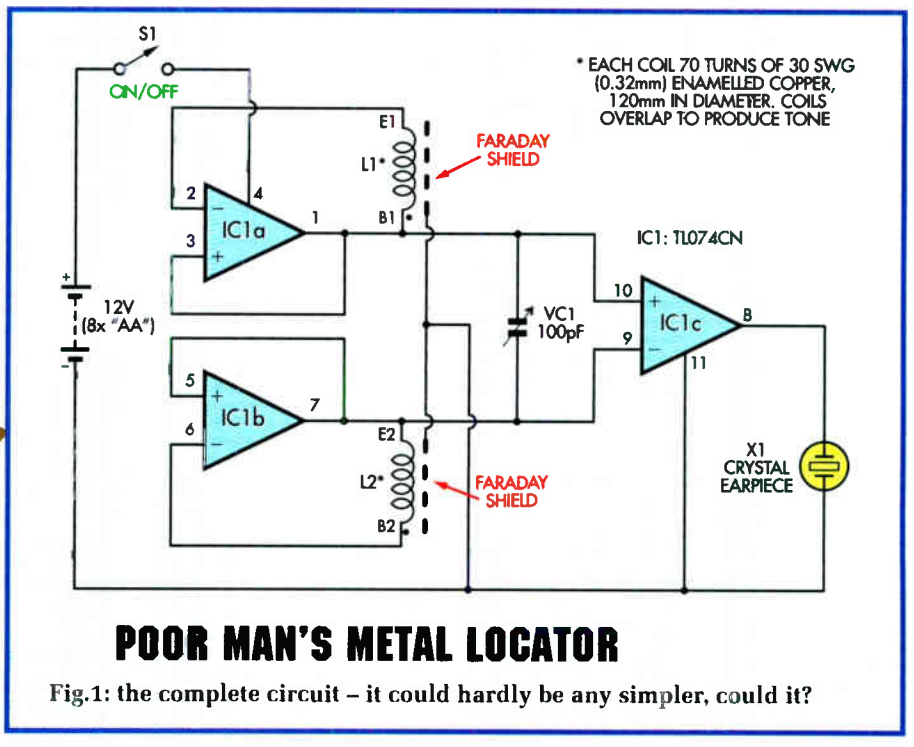


Fig.1: the complete circuit – it could hardly be any simpler, could it?

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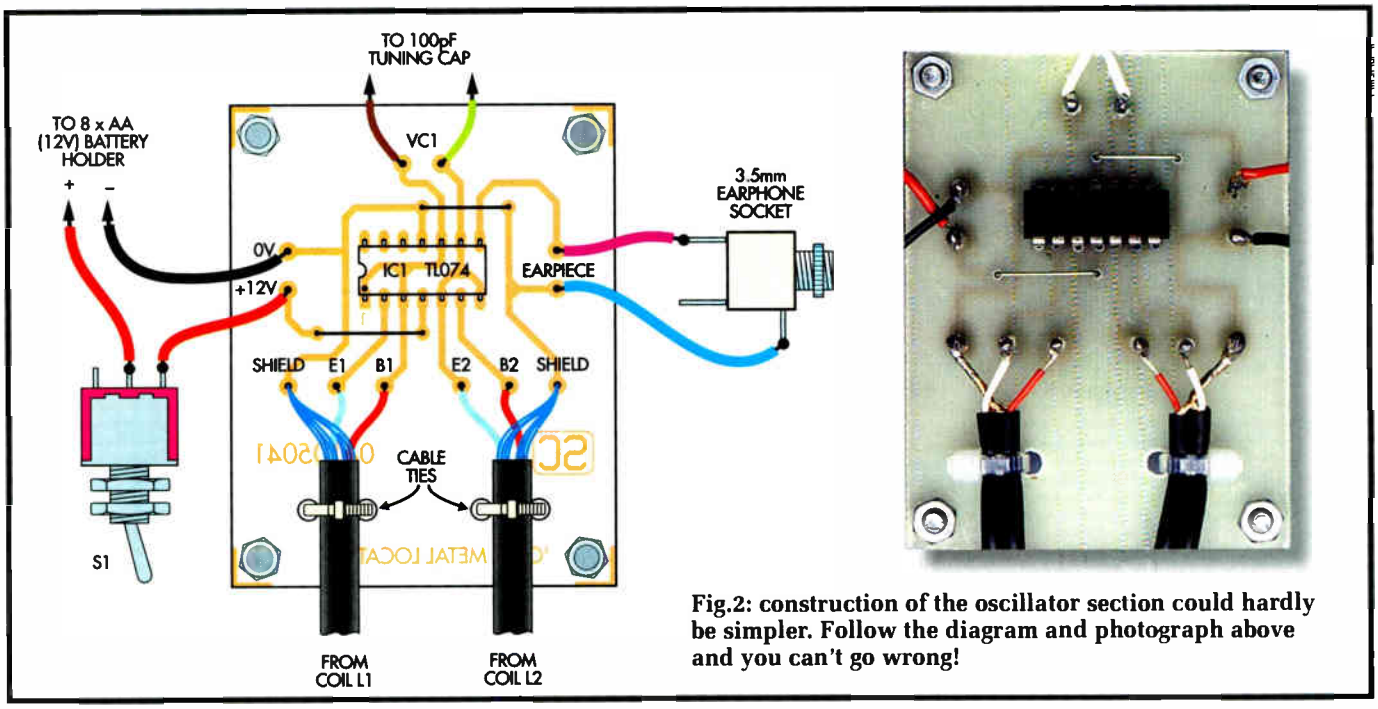


Fig.2: construction of the oscillator section could hardly be simpler. Follow the diagram and photograph above and you can't go wrong!

As the search head is swept over the ground, the presence of metal increases the inductance of L1 and then L2, or vice versa, thus bringing about a dip in the oscillator frequencies. A third op amp, IC1c, is used to mix the output of the oscillators, thus creating an audible difference frequency, or beat frequency.

This leads us to the one distinctive feature of BB. Not only does the presence of metal alter the frequency of a search oscillator but as in the case of IB, it also influences the adjacent coil. In fact, both coils influence each other through mutual induction, thus greatly enhancing the sensitivity of the system.

Beyond this, we only need to find a method of tuning the metal locator. This is achieved using variable capacitor VC1, which further couples the two inductors (the search coils), thus offering a means of controlling balance. Almost any variable capacitor should work in this position, although it should preferably have a smaller value; eg, 47pF to 100pF. A small value capacitor (eg 47pF) can be wired in series with VC1 to reduce a larger value.

A crystal earpiece is used for sound output. While a piezo sounder may be used (without integral electronics), this is not likely to offer good volume. If the volume in the earpiece is too high, use a suitable series resistor to reduce it. An inductive sounder or earpiece is not recommended, because it could overload IC1c.

Current consumption is around 15mA. Therefore an 8 × AA battery pack should last around 70 hours.

Construction

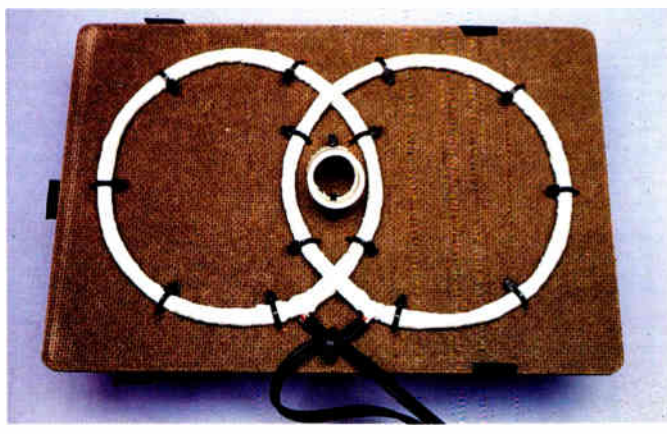
There's so little on the PC board that it would be difficult to make a mistake. OK, so you could put the IC in back-to-front, likewise the search coils' starts and ends could be inadvertently swapped. Apart from that, there's precious little to worry about.

Fit the 12 stakes to the PC board and solder them into place, then solder the two jumper wires as shown. Normally we would say use resistor lead offcuts for this – but there aren't any! You'll have to use some tinned copper wire instead.

Now comes the challenge of populating the PC board! Since this is a sensitive, high-frequency circuit, I would recommend that IC1 be soldered directly to the PC board (ie, not socketed). So long as you insert this component the right way round, there would appear to be little to go wrong! The TL074CN is a fairly "tough bird"– but be reasonably quick with the soldering iron.

Wire up the variable capacitor VC1, the socket for the crystal earpiece and the battery and switch (carefully note the polarity of the battery leads – an error here could destroy the circuit). It's usual to insert the on-off switch in the positive battery lead. Some battery holders have solder tags, others (such as the one we used) need a 9V battery snap to connect them. Again, watch the polarity!

Now mount the on-off switch and the jack socket (for the crystal earpiece) on the case. I used long bolts to clamp



Two overlapping coils are wound using 30SWG wire and fastened to a non-metallic base. Figure-of-8 screened microphone cable connects the coils to the oscillator.

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VC1 underneath the PC board and found this an easy and effective way of fixing the variable capacitor to the case. Use a slice of non-conductive rubber to isolate VC1 from the back of the PC board.

Next, wind the two search coils. They are 70 turns of 30SWG (0·315mm) enamelled copper wire on 120mm diameter formers. Faraday electrostatic shields are essential for circuit stability. These are connected to 0V and should use balanced (figure-8) screened microphone cable. Winding of the coils is not critical and a little give and take is permissible. However they should be as close as possible to identical.

Wind the coils around the formers, temporarily holding them together by passing stubs of insulating tape under them and pressing them together over the top. Once you have wound the coils, bind them tightly with insulating tape around their entire circumference. Scrape the enamel off the ends of the coils' enamelled copper wires to solder them to the microphone cables.

Now add Faraday shields. Prepare some long, thin strips of aluminium or tin-foil. Twist a 100mm length of bare wire around each coil, over the insulating tape. This wire provides electrical contact with the foil and is soldered to the microphone cable screens.

Beginning at the base of the bare wires, wind the foil around the circumference of the coils, so that no insulating tape is still visible under the foil – but the foil should not complete a full 360°.

Leave a small gap (say 10mm) so that the foil does not meet after having done most of the round. Now again tightly bind the coils with insulating tape around their entire circumference.

Attach the coils to the circuit by means of the specified microphone cables, being careful to identify the beginning and end wires correctly as shown. If these are not correctly identified, there could be a 20% loss of sensitivity. The Faraday shields should be connected to the cable screens and to 0V on the PC board as shown.

Parts List – Poor Man's Metal Locator

1 PC board, code 570 available from the *EPE PCB Service*, 51 x 64mm
1 plastic case, 150 x 90 x 50mm
1 TL074CN quad op amp (IC1)
1 10-100pF variable (tuning) capacitor, with knob
1 crystal earpiece
1 3·5mm mono earphone socket
1 8 x AA battery holder and batteries
1 battery snap (if required by holder)
1 SPST power switch
55m (approx.) 30SWG enamelled copper wire
2 lengths twin shielded balanced microphone coax (figure-8), approx. 2m long
hookup wire
2 20mm lengths tinned copper wire (for PC board links)
2 lengths of aluminium foil, approx. 20mm wide (for shield)
1 length PVC conduit to suit (handle)
4 20mm M3 screws and nuts
Suitable cable ties
Clear polyester resin

Hardware

The "hardware" construction is just as simple as the rest of the design. The two search coils are fixed to a plate of hardboard or Masonite, with a single PVC electrical conduit shaft attached. The control box, containing all of the electronics apart from the coils, attaches to the shaft via a pair of cable ties.

The top of the shaft is then held in the hand just above the control box, while its upper length rests against the back of one's forearm.

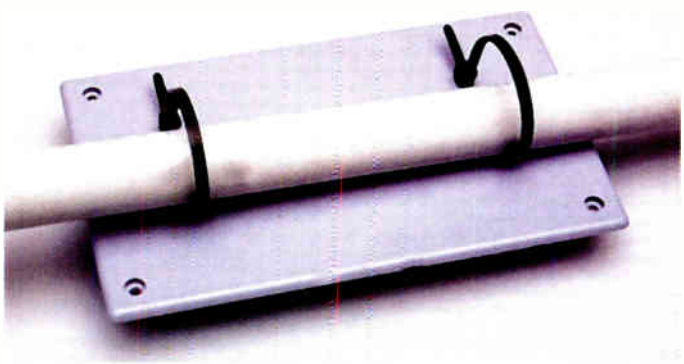
Use a stiff, non-metallic plate for the search head. Hardboard or Masonite is both stiff and easy to work with (I cut up an old Masonite clipboard for the purpose). Before the coils (or anything else) are attached to the baseplate, their best operating position needs to be determined.

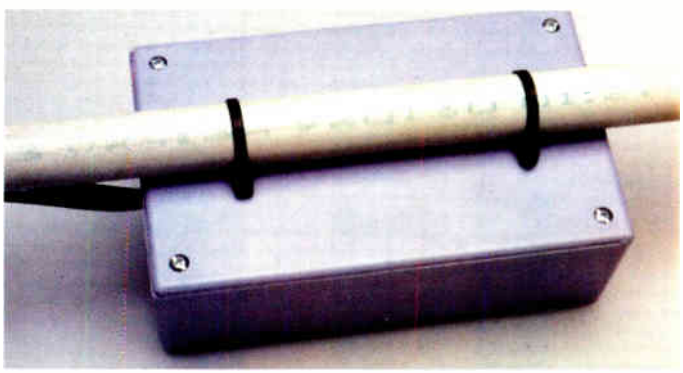
Begin by placing the two coils on the search head plate, directly on top of one another (that is, "meshed"), with their beginning and end wires positioned as shown. Turn VC1 to its mid-position. Switch the detector on, then slowly move the coils apart.

When the coils have all but been separated from one another, a tone will be heard in the crystal earpiece. Adjust the coil positions so that this is a fairly low tone – then drill holes and use cable ties (several for each coil) to fasten them in this position on the plate.

Once the cable ties have been tightened, carefully bend the coils until a low tone is again heard in the crystal earpiece. To lower the tone, create a greater overlap of the two coils (ie, a larger segment in the middle), and vice versa.

To construct a shaft, saw the end off a length of PVC piping at a 25° angle. Drill holes through the pipe close to its bottom end and holes through the centre of the search plate. Then bind the pipe to the search plate with cable ties. The pipe (or shaft) will later be fixed permanently to the search plate with clear polyester resin (see photographs).





The lid is secured to the PVC pipe by means of a couple of cable ties. When these are pulled tight, they really grip well! Then the lid (which is effectively now the base) is screwed onto the box – and presto!

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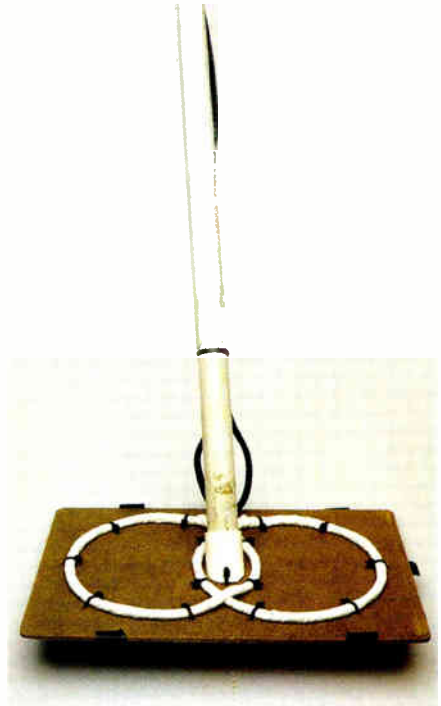

The "works" box (left) is mounted near the top of the PVC tube. This view shows the front of the box, with the earpiece socket, tuning capacitor and on/off switch. We haven't put a fancy label on this project – it would sort of ruin the effect, wouldn't it? Besides, the label would be on the underside. At right is the coil end, showing how it mounts to the PVC tube.

The two coils need to be set rigidly in position on the search head, so that they will not move even slightly when the metal locator is in use. I would recommend that they be potted in clear epoxy resin, which is available from most hardware stores, together with the necessary hardener or catalyst.

A section of one coil should be left exposed where the two coils intersect, so as to enable final fine adjustment. This section of coil may be temporarily protected with Blu-Tac.

Be sure to plug the holes beneath the search head before pouring the resin, since it is very runny and sticks faster than many glues! The detector's PVC shaft is bound to the search head with the resin.

I tied the control box to the shaft with cable ties and used a little all-purpose glue to assist. Cable ties were further used to bind the cables to the shaft. No hand grip was attached to the prototype but the shaft was kept long at the top, so as to rest against the back of my forearm as I gripped the shaft with my hand.

Checking it out

Once construction is complete and everything checked, switch on and tune VC1 until a clear difference frequency or heterodyne is heard in the crystal earpiece. This should ideally be a low tone of just a few tens of Hertz. It will be found that sensitivity is dependent to some extent on tone and some experimentation will yield the best frequency. If necessary, further adjust the coils, moving them further apart if the circuit is silent, or closer together if the frequency is too high.

Bring a metal item close to the coils. It will be found that one coil causes the tone in the crystal earpiece to rise, while the other causes it to fall, with the overlapping segment offering discrimination between ferrous and non-ferrous metals.

The detector should pick up a large coin (eg, 50p) at up to 150mm in air (125mm is a sure bet), while large metal objects (eg, a cake tin) will be detected at half a metre. At close range, it is capable of picking up a pin. When in use, hold the search head close to the ground, sweeping it to and fro. Unlike IB, the two coils give opposite responses to metal, which one soon becomes accustomed to.

While the detector is unusually stable, readjustment by means of VC1 will inevitably be required, particularly immediately after switch-on. ***EPE***

The Patent That Came Close – But No Cigar!

US Patent 4,196,391 of 1980, by Harold J Weber, was a good piece of original thinking that makes fascinating reading. It came so close to Beat Balance – but no cigar!

The patent describes a metal locator which uses two transmitters, as does ours, balanced by a variable capacitor. However, the patent seeks "least interaction between the inductors", while ours is almost entirely dependent on such interaction.

In the patent, a variable capacitor is used to balance the frequencies of the two transmitters. Ours, on the other hand, uses variable capacitor VC1 to obtain a beat frequency.

The patent mixes the two transmitter frequencies with a third frequency from a Beat Oscillator. The purpose of this is to provide binaural location of metal objects, which is the "primary object" of the patent. Ours obtains an audible heterodyne by mixing the two transmitter frequencies directly, its primary object being to boost sensitivity.

Harold J. Weber states in his patent that he is "surprised" to find "pronounced improvement" by alternating the signals in the ears – for which he employs a Gate Oscillator and a Gate Switch Driver. Why the expression of surprise? It is hardly scientific language.

My hunch is that the pronounced improvement lay not in the ears but in the coils. He considered that he had merely invented another "beat frequency detector type", thus missing a significant breakthrough by a whisker.

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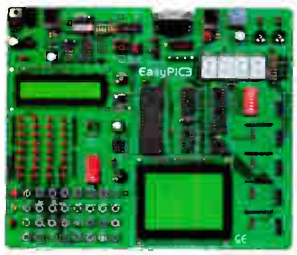

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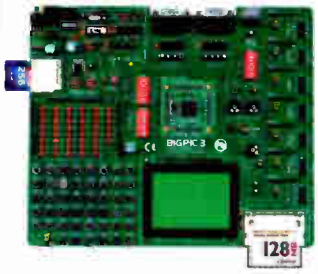

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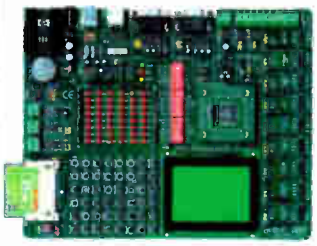

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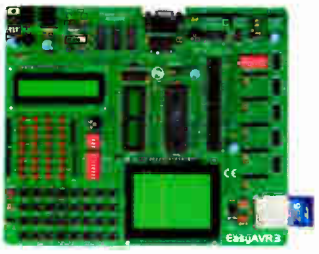

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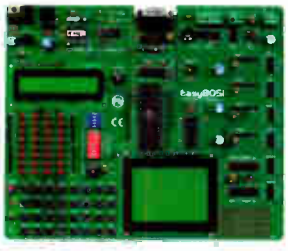

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PIC N' MIX

MIKE HIBBETT

Our periodic column for your PIC programming enlightenment

Random Number Generation

ON the whole, microcontrollers are deterministic: they faithfully follow the instructions we give them. Barring hardware faults or coding errors, when asked to perform a sequence of instructions they will execute them in exactly the same way time and time again. That's all part of the microcontroller design; every operation is synchronised to the processor clock. That's a very good thing too; when we write a piece of software we would want it to work the same way on every processor, every time it is run.

Sometimes, however, it is useful to introduce a bit of randomness into the operation of a program. In a game of hangman for example, you would want to select a random word from a dictionary; some problem solving algorithms, for example navigating a maze, can benefit from making random decisions on which path to take. In the latter case it may not always be the most efficient method but it would be simple to implement and a lot of fun to watch!

Software testing is also an area where randomness is useful, since it can provide interesting input data that the person who wrote the software may not have considered. You could run the routine in a test harness thousands of times with random input data to verify that it performs correctly with a wide range of input data.

What is Randomness?

So what exactly is randomness? Surprisingly, it's difficult to find a useful definition of the word. The *Oxford English Dictionary* offers "made, done, or happening without method or conscious decision". A more workable definition can be found in mathematics: "Being or relating to a set whose numbers have an equal probability of occurring". What this means is that given a group of "things", such as the words in a dictionary, the group of numbers between 0 and 255 or the possible directions to turn in a maze, any one of the values in that group has the same probability of being chosen as any other.

That last definition of random is nice and concise, but achieving it in real life is almost impossible. There are some natural sources of randomness; radio-active decay is probably one of the best known. While the half-life of a particular radio-active element can be clearly defined the time between decay events is completely unpredictable, and if monitored by a sensor connected to your system it would form a very good random number generator. That's not a very practical solution however, so we need to look elsewhere for our source of random numbers.

Achieving Randomness

There are two approaches to this problem: make your own, or get some pre-calculated from somewhere else. This is not as crazy as it sounds. There are many websites dedicated to generating "very random" numbers including some respectable research establishments such as Fourmilab in Switzerland. The site **www.random.org** provides further information on randomness and has a form with which you can submit requests for up to 10,000 random numbers at a time. They also, amusingly, link to an alternative site that can serve up very non-random numbers: **www.noentropy.net** – worth a quick visit!

Once you have your random numbers you can store them away in your application and just call them up one at a time. If you record the index into the table in non-volatile memory such as EEPROM, then you will be able to give the appearance of randomness, pulling a new random number out each time. This is a very fast implementation, requiring just a lookup table.

The downside is that at some point you will reach the end of the list and need to repeat again from the beginning. Also, as you will need to store between one and four bytes per entry this method would consume a large amount of non-volatile memory. Not a practical solution.

White noise, which can be created by amplifying electron noise (from a diode source for example), produces a signal which can be clipped to output a sequence of random ones and zeros. This technique requires additional analogue circuitry in your design and a software process to clock in "bits" to build up a byte or word. It will also be susceptible to interference from internal or external signals.

Linear Congruential Generator

Fortunately, there is an alternative, simple, algorithmic solution to the problem: the Linear Congruential Generator. This is a trivial equation that can be used to generate a pseudo random number sequence. "Pseudo" means that it is only an approximation; in particular, the sequence will repeat itself after a (possibly large) number of iterations. Microsoft used this system in their implementation of the BASIC programming language.

The detailed explanation behind the equation is extremely complicated. Fortunately the equation itself and its application is not. Here it is:

$$x1 = (x0 * a + b) \text{ MOD } (2^{24})$$

where x0 is the previous random number generated, x1 is the new one, "a" is the constant 1140671485 and "b" is the constant 12820163. The equation will give numbers in the range of 0 to 16777215, ie a 24 bit number.

This method can be implemented easily in any programming language, for example in C the following would do:

```
nt main(int argc, char* argv[])
{
unsigned long rndVal = 50000L;
int i;
float rndFloat;

for (i=0;i<10;i++)
{
rndVal = (rndVal * 1140671485L + 12820163) & 0xffffffL;

// rndVal returns a number less than 16777216;
// divide by 16777216 to get a fraction between 0 and 1
rndFloat = (float)rndVal / (float)16777216.0;

printf("Value is %.15f\n",rndFloat);
}
return 0;
}
```

The reasons for the choice of values "a" and "b" are complex (in an early version of Basic, Microsoft choose a bad pair, resulting in a poor random number generator) but as you can see, it is a very straightforward algorithm to translate into software.

For us microcontroller fans, however, there is a big problem: the numbers in the equation are very large, and require the use of floating point division. This would require several hundred bytes of program code and several hundred clock cycles to execute. Is there no simpler way?

Simpler PRBS Method

Fortunately, a small, simple and fast solution does exist, that can produce acceptably random numbers. The method, called *pseudo-random bit sequence generators*, comes from the electronics world. They consist of a series of shift registers with a multiple input exclusive-OR feedback to the input. Depending on the number of shift registers used and the position of feedback taps, you can create a digital signal with random characteristics that repeats after a very long series of clock.

An example is shown in Fig.1. This is a 9-bit shift register with feedback taps at positions five and nine. The two input exclusive-OR gate (shown at "B") feeds these feedback taps back into the input.

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At each shift of the circuit the last 8 bits can be copied out into a register (shown at "C") to provide a random number between 0 and 255. The circuit will produce a random bit stream that repeats after 511 cycles.

Certainly 551 cycles is not a lot, but fortunately the circuit can scale very easily. A 31-bit shift register with taps at positions 31 and 28 will not repeat for over 2000 million cycles!

One of the nice things about PRBSs is that there is a very strong similiarity between the electronics implementation and what you do in software, showing how close the two disciplines are.

Implementing PRBS

We can implement the shift registers as a series of RAM memory locations; a 31-bit shift register will require four bytes. To cycle to the next random value we simply need to perform an exclusive-OR of bits 31 and 28, shift the register to the right and stick the feedback value into the lefthand bit. You can extract your random value – 8, 16, 24 or 32-bit – from the righthand side by just reading the appropriate memory locations.

There is only one thing we need to take account of: the shift register must be given a non-zero value at the beginning. If you start with all zeros in the shift register then it will stay that way.

The code is straightforward. First, consider the initialisation of the shift register:

```
initRand
; Give the PRBS a non-zero start value
movlw     SEED_VALUE_1
movwf     shiftReg1
movlw     SEED_VALUE_2
movwf     shiftReg2
movlw     SEED_VALUE_3
movwf     shiftReg3
movlw     SEED_VALUE_4
movwf     shiftReg4
return
```

The seed value should be any non-zero value. To avoid starting at the same random value each time your application starts you should use a different SEED value when you call the initialisation routine. The simplest way is to just record the values stored in the shift register bytes into non-volatile memory and reload them in your initialisation routine. You can store them periodically or on each cycle of the PRBS, whichever is convenient.

To generate a random number, use the following:

```
generateRand
   ; XOR bits 28 and 31
   rrf     shiftReg4, W
   movwf tmpReg
   swapf  shiftReg4, W
   xorwf  tmpReg, F

   ; Put result in the Carry bit
   rrf     tmpReg, F

   ; Perform the shift
   rrf     shiftReg1, F
   rrf     shiftReg2, F
   rrf     shiftReg3, F
   rrf     shiftReg4, F
   return
```

As you can see, there is not much to it. Just nine instructions, five RAM locations used and an execution time of nine instruction cycles. Because the code is so efficient you can place it in an interrupt routine (should you wish to do so) and call it on a timer, for example once per second, to give yourself some extra "randomness". Calling it once every time you extract a random number is perfectly acceptable though. If you do update it in an interrupt, take care how you read the random number – your code may be interrupted during the read.

So finally, to read the random number, just read as many bytes from the shift register as you wish, with the "righthand" byte being the least significant. Here are some examples:

```
get8bitRand
        movfw    shiftReg4
        movwf    rand
        return

get16bitRand
        movfw    shiftReg3
        movwf    randh
        movfw    shiftReg4
        movwf    randl
        return
```

Random Entropy

When we extract data from the PRBS in this way – copying out a range of bits to form a byte or word – we are "cheating" slightly. The random nature of the PRBS is reduced, but when you consider that the bit sequence does not repeat over a 2000 million range, it is unlikely to be a problem. As with many of the choices we make when we design a system, we must make some compromises, ones that (generally!) go unnoticed by the end user.

The degree of randomness a system has is called its "entropy". It's a measure of the level of chaos or disorder in a system. If our random number generator always returned "1", it would be considered to have a very low entropy. We can increase the level of entropy in our system by making calls to the generateRand function in parts of our program that do not occur at specific times, for example when a key is pressed, or some external event occurs. Operating systems like Linux do this; when a programmer writes a device driver for the Linux kernel they can signal to the kernel that it can contribute to the system entropy (due to the random nature of incoming events for example.)

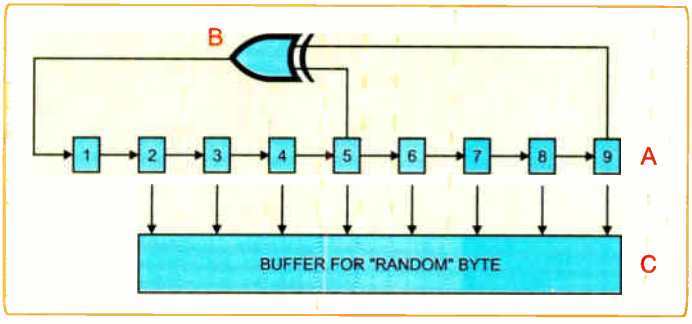

Fig.1. Flow chart of simple PRBS method

An Illusion

Computers are purely deterministic; what they do can always be predicted. Our PRBS generator will provide the illusion of randomness, but it will always be an illusion.

In some cases, such as software testing, this is actually a benefit. If a particular sequence of pseudo random test values causes a problem, they can always be regenerated if the starting point is known. The generator detailed above will produce exactly the same 2000 million sequence if it is run on a PIC, a PC or the largest super computer.

To improve the randomness of your generator consider using external events (such as time elapsed between keypresses or incoming serial bytes) to increase the entropy. True randomness is an unachievable goal but an acceptable, workable compromise is perfectly possible with an incredibly small code and memory overhead. May your next project be truly unpredictable!

An example of the practical use of a PRBS is used in the software of the PIC Sudoku *unit to be published next month. Ed.*

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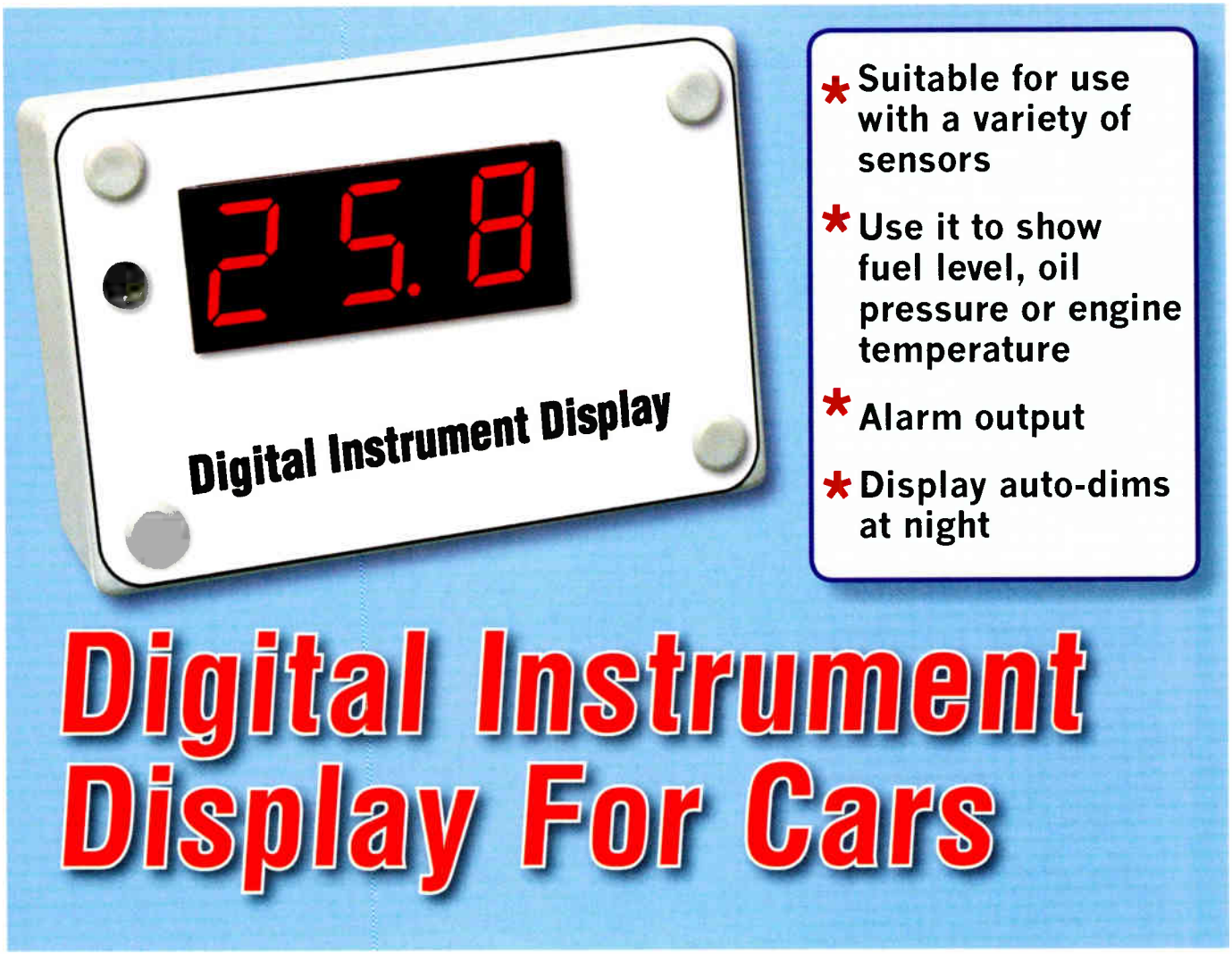

Digital Instrument Display For Cars

Based on a PIC microcontroller, this simple project lets you convert the analogue instruments in your car to a digital display. It's suitable for use with fuel gauges, oil pressure gauges and temperature gauges, and even features an alarm output.

Pt.1: By JOHN CLARKE

MOST cars have analogue readouts for displaying fuel level and engine temperature. Similarly, the oil pressure is either shown on an analogue gauge or more commonly, there's no gauge and just an "idiot" warning light instead.

Of course, there's nothing wrong with analogue gauges – it's just that some drivers would rather have these outputs displayed in digital format instead.

That's where this Digital Instrument Display comes in – it's designed to operate with any sensor or sender unit which varies its resistance or voltage signal output and display the result on a 3-digit LED readout. Basically, it's ideal for use with sender units that have relatively slow changing values; eg, as found in fuel level, oil pressure and temperature gauges.

In operation, the unit can be calibrated so that the display will show any value in the range from -99 through to 999. The decimal point can also be placed in one of two positions, so that the values can be from -.99 to 9.99 or from -9.9 to 99.9. In addition, the unit can be calibrated to display metric or imperial units.

Alternatively, the values do not need to relate to any particular unit and could refer to percentages instead – eg, 100% for full.

Of course, fuel and temperature gauges don't usually show precise values. Instead, they give a general indication of how things are going – eg, remaining fuel level somewhere between full and half-empty, or temperature midway between hot and cold. By contrast, you can calibrate this digital display unit to show the actual values – eg, fuel remaining in litres (or gallons if you prefer) or engine temperature in °C or °F, or some other function.

In practice, the Digital Instrument Display is calibrated at two values

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and the instrument calculates the remaining values from these in a linear fashion. For example, if the unit is to be used as a fuel gauge, it is best calibrated when the fuel tank is full (eg, 55 litres fuel) and then calibrated when the tank is close to empty (eg, 10 litres). The display will then subsequently be able to show the remaining fuel in the tank (in litres) over the complete range from full to empty.

Alarm output

An alarm output is available to warn of impending "doom". For example, it could be set to trigger an alarm when the fuel tank approaches empty. Alternatively, it could be used to alert the driver if the engine is overheating or if the oil pressure is too low.

In operation, the unit is set up to trigger the alarm when the display reading goes above or below a particular value. Under alarm conditions, the righthand decimal point lights as a visual indication. In addition, the alarm output can also drive a low-current piezo siren if an audible indication is required or it can be used to trigger an external relay-driver circuit.

Presentation

The unit is housed in a small plastic case, with the display showing through a transparent red Perspex or acrylic window.

There are no user controls on the front panel. Instead, the three calibration switches (Mode, Up and Down) are hidden behind the front panel as they are not needed once the unit has been calibrated.

Different modes

The Mode switch is used to display the calibration values. On the first press, the display initially goes blank and then shows the first calibration value. This value is initially set at "0" and can be changed to any number up to 999 (disregarding the decimal point) using the on-board Up and Down switches.

Pressing the Mode switch again then brings up the second calibration value. This is initially set at 100 but again can be set to any number from 0-999 using the Up and Down switches.

Similarly, pressing the Mode switch a third time brings up the alarm value and once more, this is adjusted using the Up and Down switches. The sense of the alarm can also be set – ie, so that it is either on for values above the alarm setting (and off for values below this) or on for values below the alarm setting.

The required alarm sense is selected at power up. Pressing the Mode switch when power is first applied will keep the display blank and upon release the display will show either AL or AL-. An "AL" display indicates that the alarm will be on for values above the alarm value and off for values below the alarm value.

Conversely, an "AL-" display indicates that the alarm will be off for values over the alarm setting and on for values below this.

To change from one to the other, you simply switch off the power and then hold down the Mode switch and apply power again. The display will now show the alternative setting when the switch is released.

Returning now to the normal Mode switch operation, the fourth press of this button displays the actual measured value of the voltage applied to the input of the unit. This is to allow the unit to be set up correctly – ie, it allows you to ensure that the applied input voltage is within the permissible range.

The fifth pressing of the Mode switch brings up three dashes (- - -) for a short period, after which the unit returns to the "normal" display mode. In this mode, it displays the calculated value, which is based on the input voltage and calibration values. In this mode, the alarm LED will either be lit or unlit, depending on the alarm setting and the input signal level.

In summary, at power up, the display is in its normal mode. Repeatedly pressing the Mode switch then brings up the following modes: 1 – First Calibration Value; 2 – Second Calibration Value; 3 – Alarm Threshold; 4 – Measured Input Level; and 5 – Normal Mode again. Modes 1-4 are all indicated with a flashing alarm LED.

Circuit details

Fig.1 shows the circuit for the Digital Instrument Display. It's dominated by IC1, a PIC16F84-10P microcontroller. This monitors the input signal voltage via comparator stage IC2a, processes the information and drives the three 7-segment LED displays (DISP1 – DISP3).

OK, let's start with the input sensing circuit. In operation, the incoming analogue signal from the sensor (or sender) is filtered using a 10kΩ resistor and 100µF capacitor and fed to pin 2 of comparator stage IC2a. Note that provision has been made for a pullup resistor directly at the input, since this will be necessary with some sensors. Similarly, resistor R2 can be used to attenuate the input signal if necessary (more on this later).

In operation, IC2a compares the voltage on its pin 2 input with a DC voltage on its pin 3 input. This DC voltage is derived by applying a pulse-width modulated (PWM) square-wave signal from the RA3 output of IC1 to a 390nF capacitor via a 200kΩ resistor and trimpot VR2.

As a result, pin 1 of IC2a switches low whenever the voltage on its pin 2 input is greater than the voltage on pin

MAIN Features

- Suitable for connection to variable resistance or voltage output sensors.
- Programmable display values; shows readout on a 3-digit LED display.
- Alarm output signal with visual alarm output indication at righthand decimal point.
- Adjustable alarm level.
- Can be set to alarm either above or below set value (optional).
- Displays values from 999 maximum to -99 minimum.
- Decimal point selection at x.xx or xx.x position (optional).
- Automatic display dimming in low light levels.
- 2-second display update period.

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Parts List

1 Microcontroller PC board, code 571, available from the *EPE PCB Service*, 78 x 50mm
1 Display PC board, code 572, available from the *EPE PCB Service*, 78 x 50mm
1 front panel label 80 x 53mm
1 plastic utility case measuring 83 x 54 x 30mm
1 Perspex or Acrylic transparent red sheet, 56 x 20 x 3mm
1 10MHz parallel resonant crystal (X1)
1 LDR
3 SPST micro tactile switches
5 PC stakes
3 7-way pin header launchers
1 DIP18 socket for IC1
2 DIP14 low cost IC sockets with wiper contacts (cut for 3 x 7-way single in-line sockets)

Screws & spacers
1 9mm long x 3mm ID untapped brass spacer
1 10mm long x 3mm ID tapped Nylon spacer (can be made from 2 x 6mm spacers with one cut to 4mm)
2 6mm long M3 tapped Nylon spacers
2 M3 x 6mm screws
1 M3 x 15mm brass screw
1 M3 x 15mm Nylon screw

Wire & cable
1 300mm length of 0.7mm tinned copper wire
1 2m length of red automotive wire
1 2m length of yellow automotive wire
1 2m length of black or green automotive wire (ground wire)

Semiconductors
1 PIC16F84-10P or PIC16F84-20P microcontroller programmed with INSTRUM.HEX, available for download from the *EPE* website at **www.epemag.co.uk** (IC1)
1 LM358 dual op amp (IC2)
1 7805 5V 1A 3-terminal regulator (REG1)
3 BC327 PNP transistors (Q1-Q3)
1 BC547 NPN transistor (Q4)
2 BC337 NPN transistors (Q5,Q6)
3 HDSP5301, LTS542A common anode 7-segment LED displays (DISP1-DISP3)
1 3mm red LED (LED1)
1 LM336-2.5 reference diode (REF1)
1 16V 1W Zener diode (ZD1)
4 1N914 switching diodes (D1-D4)

Capacitors
2 100µF 16V PC electrolytic
3 10µF 16V PC electrolytic
1 390nF (0·39µF) MKT polyester
2 100nF (0·1µF) MKT polyester
2 18pF ceramic

Trimpots
1 20kΩ horizontal trimpot (VR1)
1 250kΩ horizontal trimpot (VR2)
1 500kΩ horizontal trimpot (VR3)

Resistors (0·25W, 1%)

1 1MΩ	1 1kΩ 0.5W
1 200kΩ	3 680Ω
7 10kΩ	10 150Ω
2 3·3kΩ	1 10Ω 1W

Miscellaneous
Automotive connectors, heat-shrink tubing, cable ties, etc.

3. This signal is then fed via a 3·3kΩ limiting resistor to the RB0 input of IC1. This resistor limits the current from IC2a when its output switches high to a nominal 12V, while internal clamp diodes at RB0 limit the voltage on this pin to 5·5V.

A-D converter

Among other things, IC1 functions as an analogue-to-digital (A-D) converter. In operation, it converts the comparator signal on its RB0 (pin 6) input to a digital value which is then used to drive the 3-digit LED display.

The A-D converter used here operates by using a series of successive approximations and involves just two external connections to IC1. As mentioned earlier, IC1 produces a PWM signal at its RA3 output and this operates at 4·882kHz with a wide-ranging duty cycle. Note that a high output from RA3 is at 5V while a low output is at 0V.

The RC network on RA3 filters this PWM waveform to derive a DC voltage that is the average of the PWM waveform. This means that if the duty cycle is 50% (ie, a square wave), the average at RA3 will be 50% of 5V or 2·5V. Varying the duty-cycle either side of 50% produces higher or lower DC voltages accordingly.

Operation of the A-D converter is as follows: initially, the RA3 output is set to a 50% duty cycle and this sets the voltage at pin 3 of IC2a at 2·5V. At the same time, an 8-bit register inside IC1 has its most significant bit set high so that its value will be 10000000.

During this process, the comparator's output is monitored by IC1's RB0 input. If the measured voltage is lower than 2·5V, IC2a's output is high and the PWM output at RA3 is reduced to a 25% duty cycle to produce an average of 1·25V. The internal register is now set to 01000000.

Alternatively, if the measured voltage is above 2·5V, corresponding to a low comparator output, the RA3 output is increased to a 75% duty cycle to provide an average of 3·75V. The register is thus set to 11000000, with the most significant bit indicating a 2·5V 50% duty cycle and the next bit indicating the 1·25V 25% duty cycle (adding the two bits gives us the 3·75V).

The comparator output is again checked, after which the microcontroller adds or subtracts a 12·5% duty cycle (0·625V) and compares this against the input voltage again. The register is then set to X1100000 (with X a 1 or 0 as determined by the previous operation) if the input voltage is higher than the PWM waveform.

Conversely, if the input voltage is lower than the PWM voltage, the register is set to X0100000.

This process continues for eight cycles, the microcontroller progressively adding or subtracting smaller amounts of voltage (ie, 0·312V, 0·156V, 0·078V, 0·039V and 0·0195V) and the lower bits in the 8-bit register being either set to a "1" or a "0" to obtain an 8-bit A-D conversion.

Further resolution is obtained by altering the counter that's used to generate the PWM output. By adding or subtracting a number to the count, we can alter the filtered PWM signal by a small amount – corresponding to

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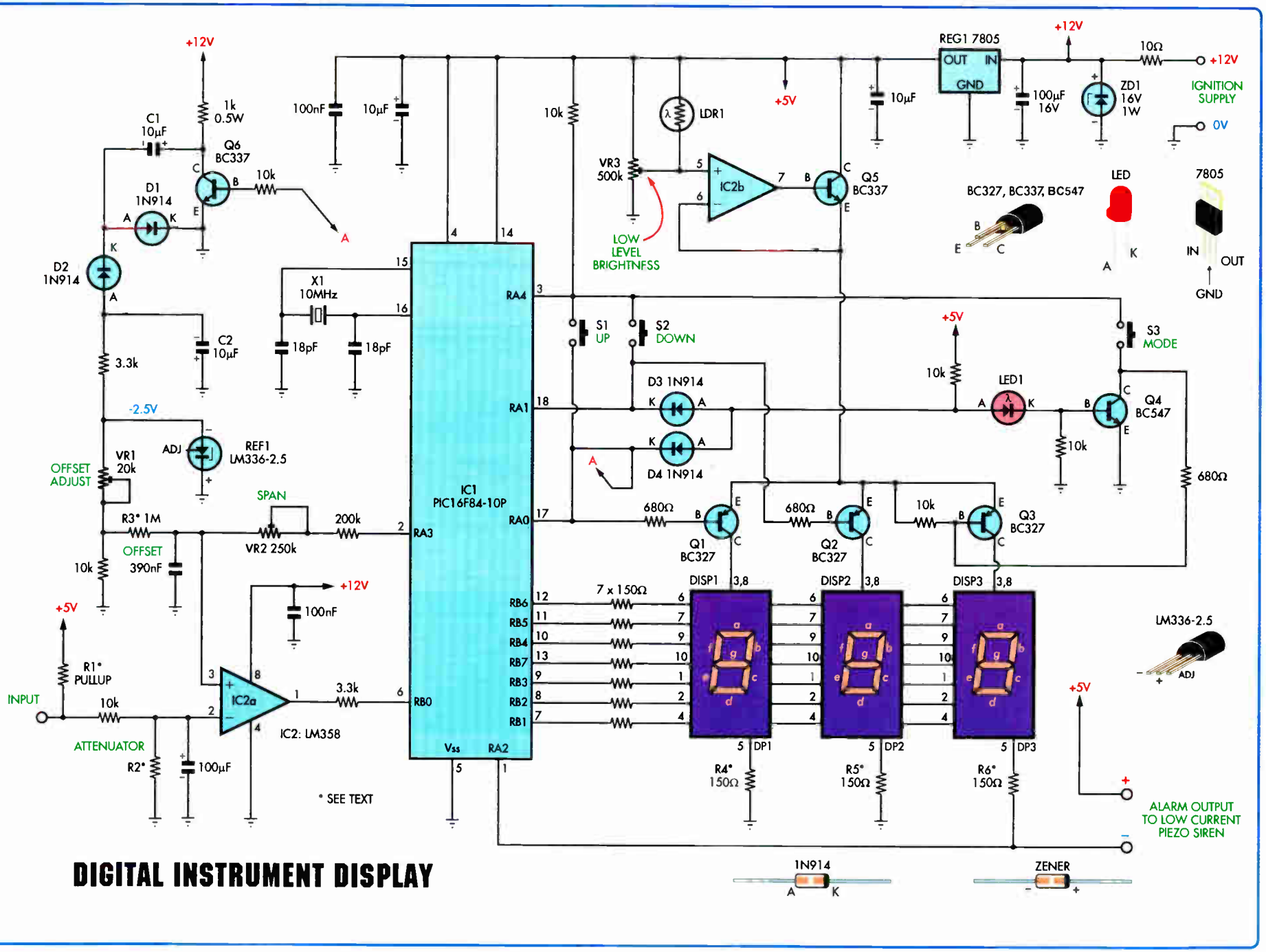

DIGITAL INSTRUMENT DISPLAY

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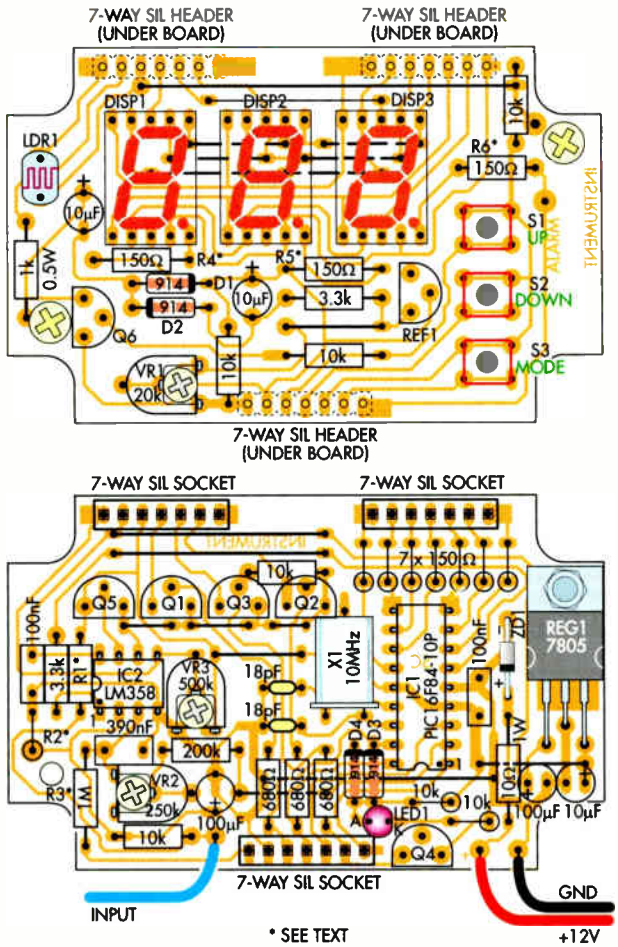

Fig.2: install the parts on the PC boards as shown here . In particular, be sure to install the 7-segment LED displays with their decimal points at bottom right and take care not to get the transistor types mixed up.

9·76mV, 4·88mV and 2·44mV – so that we obtain an 11-bit A-D conversion.

The A-D conversion thus has a resolution of around 2·44mV at the least significant bit. The possible number of values for the 11-bit register is from 00000000000 (0) to 11111111111 (2047).

In practice, we are limited to a range from about 152 to 1848 because the software must have time for internal processing to produce the waveform at the RA3 output. This means that the input signal can only be measured over a particular range of voltage corresponding to the 152 minimum count and the 1848 maximum count.

This corresponds to about 373mV minimum and 4·5V maximum.

Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
390nF	0.39µF	394	390n
100nF	0.1µF	104	100n
18pF	18pF	18	18p

However, it's quite common for automotive sensors to produce signals all the way down to 0V, so we need to cater for this type of sensor. That's done by applying a negative voltage to pin 3 of IC2a, to offset the 375mV minimum from the A-D converter.

This offset voltage is derived from voltage reference REF1, diodes D1 & D2 and transistor Q6 and its associated components.

Q6 is driven by the RA0 output of IC1. When the RA0 output is low, Q6 is off and capacitor C1 charges via a 1kΩ resistor (which connects to the 12V supply) and via diode D1. When the RA0 output subsequently goes high, Q6 turns on and connects the positive side of C1 to ground. As a result, the other end of C1 goes negative and this charges capacitor C2 via diode D2.

C1 is again charged when Q6 turns off, while D2 now becomes reverse biased and prevents C2 from discharging via this path. Instead, the negative voltage across C2 is applied to voltage reference diode REF1 via a 3·3kΩ resistor to produce a fixed -2·49V reference voltage, This voltage is then applied to pin 3 of IC2a via VR1, a 10kΩ resistor and a 1MΩ resistor (R3).

In practice, VR1 is adjusted so that the applied voltage offsets the 390mV minimum output from the A-D converter.

LED displays

The 7-segment display data from IC1 appears at outputs RB1-RB7 and

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	200kΩ	red black yellow brown	red black black orange brown
❑	7	10kΩ	brown black orange brown	brown black black red brown
❑	2	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	3	680Ω	blue grey brown brown	blue grey black black brown
❑	9	150Ω	brown green brown brown	brown green black black brown
❑	1	10Ω	brown black black brown	brown black black gold brown

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these directly drive the cathodes of the three LED displays (DISP1-3) via 150Ω current limiting resistors. Note that the segments common to each display are connected together – ie, the "a" segment cathodes are all connected together, as are the "b" segments and so on.

The displays are driven in multiplex fashion, with IC1 switching its RA0 & RA1 lines low in sequence to drive transistors Q1 & Q2. For example, when RA0 goes low, Q1 turns on and applies power to the common anode connection of DISP1. Any low outputs on RB1 – RB7 will thus light the corresponding segments of that display.

After this display has been on for a short time, the RA0 output is taken high and DISP1 turns off. The 7-segment data on RB1-RB7 is then updated, after which RA1 goes low to drive Q2 and display DISP2.

Transistor Q3, which switches power to DISP3, is driven in a different manner to Q1 & Q2. This transistor is off when either RA0 or RA1 is low (ie, if one of the other displays is on). That's because a low on RA0 or RA1 holds LED1's anode low (ie, at 0·6V) via either diode D4 or D3. As a result, LED1 cannot conduct and so Q4 is off.

However, when RA0 and RA1 are both high, D4 and D3 are reverse biased and Q4's base is pulled high via the 10kΩ resistor on LED1's anode. This turns Q4 on which in turn pulls Q3's base low via a 680Ω resistor. And that, in turn, turns Q3 on and lights display DISP3.

Of course, in practice, DISP1, DISP2 & DISP3 are switched on and off at a very fast rate, so that they appear to be continuously lit.

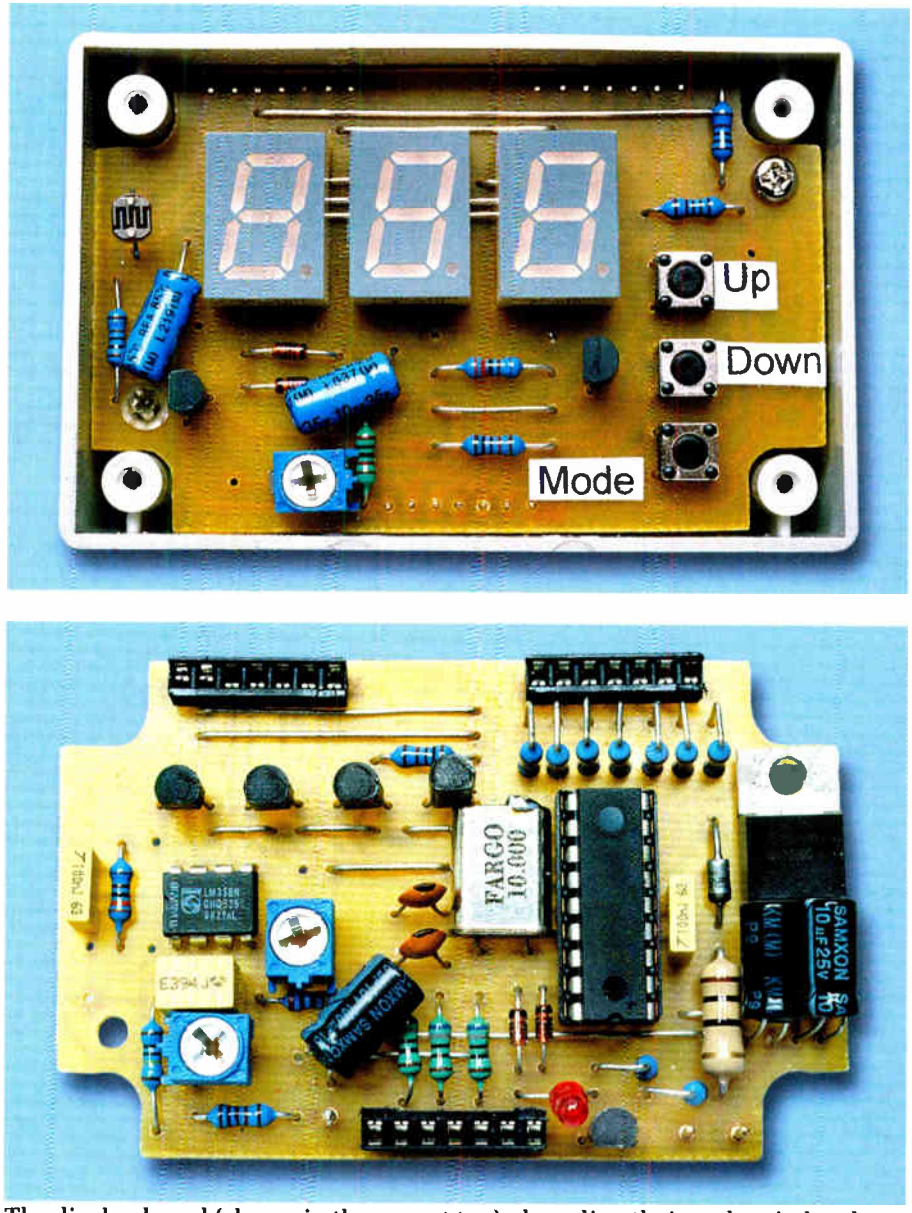
Finally, note that the decimal point (pin 5) of DISP3 is connected to IC1's RA2 output. RA2 is the alarm output and it normally switches low and turns on DP3 under alarm conditions. It can also be used to activate a low-current piezo siren which has its other side connected to the +5V rail.

Display dimming

Op amp IC2b is used to control the display brightness. This stage is wired as a unity gain amplifier and drives transistor buffer stage Q5 which is inside the negative feedback loop.

Light dependent resistor LDR1 varies the voltage on pin 5 of IC2b according to the ambient light level. In daylight, the voltage on pin 5 (and thus on pin 7) is close to +5V because the resistance of the LDR is low. This means that Q5's emitter will also be close to +5V and so virtually the full supply rail is applied to the emitters of transistors Q1-Q3 and the displays operate at full brightness.

As the ambient light falls, the LDR's resistance increases and so the voltage on pin 5 of IC2b decreases. And when it's completely dark, the voltage on pin 5 is determined by the setting of trimpot VR3 which sets the minimum brightness level. As before, the voltage on pin 5 appears at Q4's emitter and so the displays operate with reduced brightness.



The display board (shown in the case at top) plugs directly into the pin header sockets on the processor board (above), eliminating wiring connections between the two. Notice how the electrolytic capacitors on the two boards are bent over (see text), to prevent them fouling other parts.

Mode switches

Switches S1-S3 are all monitored using the RA4 input which is normally at 5V due to a 10kΩ pullup resistor. The other sides of S1 and S2 are connected to the RA0 and RA1 outputs respectively, while S3 connects to Q4's collector.

This means that pressing S1 will pull RA4 low when RA0 is low. Similarly, S2 can pull RA4 low when RA1 is low, while S3 can pull RA4 low when both RA0 and RA1 are high. As a result, the microcontroller can

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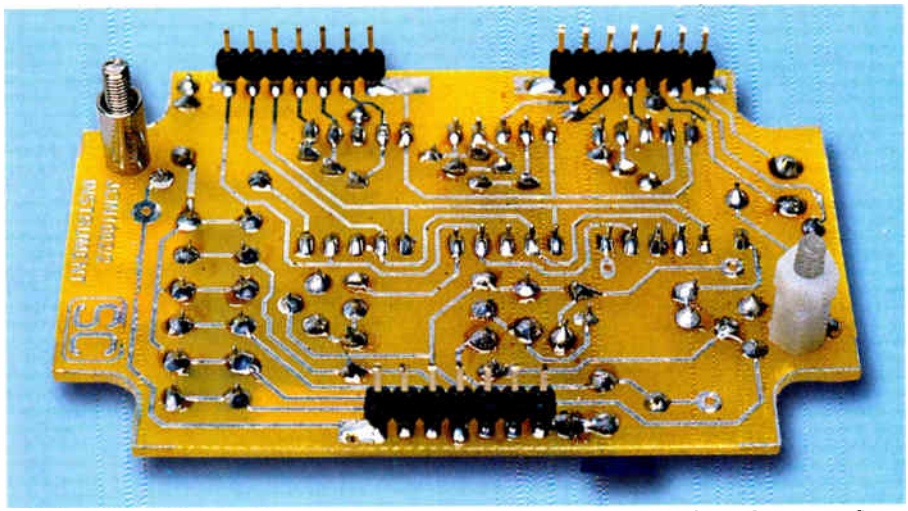
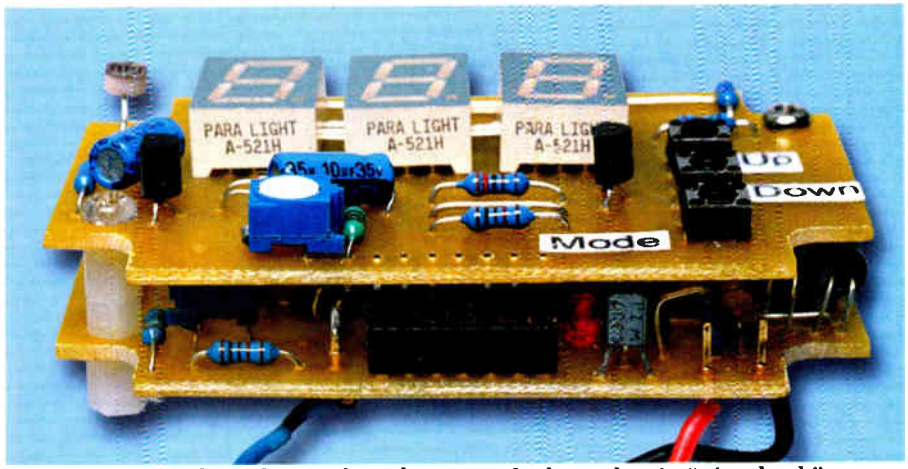


The pin headers are installed on the track side of the display board using a fine-tipped soldering iron. Note that it will be necessary to slide the plastic spacers along the leads to allow room for soldering.



This view shows how the two boards are stacked together in "piggyback" fashion to make a compact assembly. Make sure that none of the parts on the processor board contact the back of the display board.

determine which switch has been pressed when RA4 goes low, by checking the status of both RA0 and RA1.

Clock signals for IC1 are provided by an internal oscillator circuit which operates with crystal X1 (10MHz) and two 18pF capacitors. The two capacitors provide the correct loading for the crystal and ensure that the oscillator starts reliably.

The crystal frequency is divided down internally to produce clock signals for the microcontroller operation and for the display multiplexing.

Power

Power for the circuit is derived from the vehicle's ignition supply line. A 10Ω 1W resistor and a 100µF capacitor decouple this supply line, while 16V Zener diode ZD1 protects the circuit against transient voltage spikes.

The decoupled ignition supply is then fed to regulator REG1 which provides a +5V rail. This rail is then used to power the microcontroller and display circuitry, while IC2 and Q6 are powered directly from the decoupled ignition supply (+12V).

That completes the circuit description. Of course, most of the clever stuff takes place inside the PIC microcontroller under software control. You can purchase a pre-programmed PIC from Magenta Electronics or download the source code (instrum.asm) from the *EPE* website if you want to figure out how it works. The source code is fully commented, so you shouldn't have too much trouble.

Construction

All the parts are mounted on two PC boards: (1) a microcontroller board coded 571, and (2) a display PC board coded 572. These boards are stacked together using pin headers and sockets to make the interconnections, so there's no external wiring (apart from the power supply and sensor connections).

Fig.2 shows the assembly details. Begin by checking the PC boards for shorts between tracks and possible breaks and undrilled holes. That done, install all the wire links on both boards. It is important that these be installed now, as other parts mount over the top of some of the links.

You can now concentrate on building the microcontroller board. Begin by installing all the resistors using Table 1 as a guide to determining the correct values. It's also a good idea to check them using a digital multimeter, just to make sure.

Note that some of the resistors including the 7 × 150Ω units at top right, are mounted end-on to save space. Leave out R1 and R2 for the time being but be sure to install R3 (1MΩ) as shown.

Next, install a socket for IC1 (taking care with its orientation), then install IC2, Zener diode ZD1 and diodes D3 & D4. That done, install REG1 by bending its leads down by 90° so that its metal tab sits flat against the PC board. Make sure that the hole in the metal tab lines up with the hole in the PC board before soldering the leads.

Trimpots VR2 & VR3 can go in next (don't get them mixed up), followed by the capacitors. Note that the two electrolytic capacitors near the regulator must be mounted so that their bodies lie flat against REG1's leads (see photo). Similarly, the 100µF capacitor near VR2 must be mounted so that it lies between the adjacent 200kΩ and 680Ω resistors (see photo).

In practice, this simply involves bending the capacitor leads down by 90° before installing them on the board. Note that the two electrolytic capacitors near REG1 are oriented in opposite directions.

Next, install three PC stakes at the external wiring points, then install the transistors. Q1 – Q3 are all BC327s (*PNP*), while Q5 is a BC337 *NPN* type so don't get it mixed up with the others. The remaining transistor on this board (Q4) is a BC547.

Crystal X1 also mounts horizontally on the PC board. It is secured by soldering a short length of tinned copper

World Radio History

wire between the end of its metal case and an adjacent PC pad.

Finally, the three 7-way in-line sockets can be fitted. These are made by cutting two 14-pin IC sockets into single in-line strips using a sharp knife or a fine-toothed hacksaw. Clean up the rough edges with a file before installing them on the microcontroller board.

Display board

Now for the display board. The wire links should already be in place but if not, install them now, followed by the resistors, diodes and trimpot VR1. **At this stage, you can also decide if you want the decimal point showing. Install R4 if the display is to show x.xx, or R5 if the display is to show xx.x instead. Alternatively, do not install either resistor if the decimal point is not required.**

Next, install the three 7-segment LED displays with their decimal points at bottom right. REF1, Q6 (BC337) and the two electrolytic capacitors can then be installed. As before, the two electrolytics are installed so that their bodies lie fat against the PC board.

The LDR is mounted so that its top face is about 3mm above the displays (it can go in either way). Install it now, followed by the three pushbutton switches.

Finally, complete the display board assembly by installing the pin headers. These are installed from the copper side of the board, with their pins protruding about 1mm above the top surface.

You will need a fine-tipped iron to solder these pin headers. Note that you will also have to slide the plastic spacers along the pins to give sufficient room for soldering.

Preparing the case

Work can now begin on the plastic case. First, use a sharp chisel to remove the integral side pillars, then slide the microcontroller board in place and use it as a template to drill two mounting holes in the base – one through the hole in REG1's tab and the other immediately to the left of R3.

In addition, you will have to drill a hole in the back of the case to accept the power leads, plus an extra hole for the input signal lead.

Once that's done, plug the display board into the microcontroller board and secure them together using machine screws and spacers as shown in Fig.3. Check that the leads from the parts on the display board do not interfere with any parts on the microcontroller PC board. If necessary, trim the leads of the display board parts to prevent this.

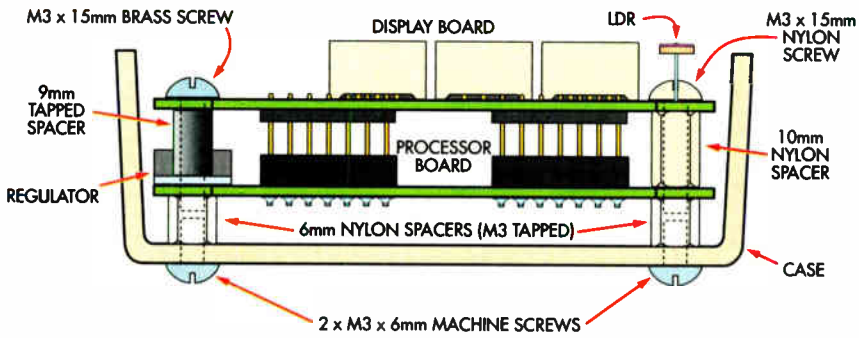


Fig.3: follow this diagram when stacking the boards together and be sure to use plastic spacers where indicated.

The front panel artwork (to be published next month) can now be used as a template for marking out the display cutout and the position of the hole for the LDR. That done, drill the LDR hole and drill a series of closely-space holes around the inside perimeter of the rectangle for the display cutout.

The centre-piece can then be knocked out and the job filed to a smooth finish.

Be sure to make the cutout just large enough, so that the red Perspex or acrylic window is a tight fit. This window can then be further secured by applying several small dabs of super glue along the inside edges.

Testing

It is best to check the power supply before plugging the microcontroller IC into its socket.

To do this, first unplug the display board and put it to one side. That done, connect the +12V and GND leads to the microcontroller board, apply power and use a multimeter to check that there is +5V on pins 4 & 14 of IC1's socket (use REG1's metal tab for the GND connection).

If this is correct, disconnect power and insert IC1 in place, ensuring that it is oriented correctly. That done, plug the display board back in and apply power with the input lead connected to ground. The display should light and show three dashes (- - -).

After about two seconds, the display should then show a number. Our prototype showed -4, but this will depend on the settings of VR1 and VR2.

Now press the Mode switch – the display should now show "0" and the alarm LED should flash. Pressing the Mode switch again should now cause the display to show "100". Press it again and the display should show 50, while the fourth press should bring up the current input reading.

Our prototype showed 97 but this will again depend on the settings for VR1 and VR2.

Now test the dimming feature by holding your finger over the LDR. Adjust VR3 until the display dims. Note: this trimpot is best adjusted in the dark to set the minimum brightness.

Finally, check that there is -2·5V at the negative terminal of voltage reference REF1. Note, however, that this voltage could vary from this value by about 200mV due to tolerances in the reference.

Next month

That's all we have space for this month. In Pt.2 next month, we will describe how to connect different sensors to the unit and describe the calibration procedure for these various sensors. ***EPE***

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World Radio History

TECHNO-TALK

MARK NELSON

THE MEMORY LINGERS ON

Do you ever wonder how some electronic and electrical manufacturers got their name? If so, join Mark Nelson on a ramble down Memory Lane.

"FERRANTI, Plessey legacy fuels analogue start ups." That was the intriguing headline of an article in the trade paper *Electronics Weekly* recently and I had to read on to find out what it was all about.

The story in fact concerned the burgeoning number of new British start-up companies specialising in analogue, rather than digital, integrated circuits. It quoted Hans Rohrer, head of analogue chips company Zetex, saying "There's more analogue talent in the UK than in other regions because of Marconi, Ferranti and Plessey. The good old Ferranti and Plessey bipolar processes can go down to voltage levels you can't do with CMOS. Europe has more bipolar designs than the rest of the world put together."

Fraud Leads To Bankruptcy

It's nice to know that Britain still excels in something but where did Ferranti, Marconi, Plessey and all the other grand old electronics companies go? Ferranti's semiconductors division became Zetex Semiconductors, the company from which Mr Rohrer in fact hails.

Fortunately for Zetex, it parted from the rest of the Ferranti dynasty before the main company became embroiled in a disastrous takeover that in 1993 ended in bankruptcy. The surviving divisions either became independent companies or were taken over by GEC-Marconi. A breakaway company, Dennis Ferranti Meters, which made telephones for British Telecoms, had split off already in 1951 and is still going strong.

GEC and Marconi merged in 1968. Marconi Electronic Systems, later GEC-Marconi, was the defence arm of GEC and was sold to British Aerospace in 1999 to become BAe Systems, whilst GEC itself was renamed Marconi plc the same year. The majority of the business was sold to Swedish Ericsson in January of this year, with the remainder taking the new name of Telent. Incidentally, there was never any connection between the British GEC and General Electric of America, despite the similarity of their trademarks; the British firm was founded several years before the US corporation.

Unhappy Merger

Plessey and GEC became embroiled in rival takeover bids in the 1980s, resulting in an unhappy merger called GEC-Plessey Telecommunications (GPT) that seemingly managed to perform worse than either of the partners' previous incarnations. Somehow or other Plessey South Africa stayed out of the fray and a few years ago launched its products on the UK market, complete with the old Plessey oscilloscope trace "twiddle". Since then, however, it has changed its name to the less alluring Tellumat.

What's In A Name?

But where did these names come from? Marconi and Ferranti are straightforward Italian surnames, whilst Plessey was both the name of an original shareholder, Plessey Parker, and also the home village of the founder's wife.

Other trade names are more complex, however. You may well remember the name Pifco but be unaware that it was established in Manchester in 1900 as the Provincial Incandescent Fittings Company. Unless you have a long memory for old advertisements, you will probably not recall that soldering iron manufacturer Antex was originally the Anglo-Netherlands Technical Exchange.

Exide was the trade name of The Electric Storage Battery Company and was introduced in 1900, short for "Excellent Oxide". Vidor, another battery company, was run by a Mr Thomas Cole and folklore has it that he named the product after his daughters Violet and Doris. It appears, however, that the daughters were actually called Valerie and Denise, with the 'R' coming from the name of his wife Rebecca.

Disputed Provenance

Another name with a disputed provenance is AMPEX, famous over several decades for tapes and tape recorders. What is not in doubt is that AMP are the initials of its founder, Alexander Michael Poniatoff. For the EX you can take your pick, as some say it stands for excellent whilst others argue in favour of experimental.

The AMP in AMP connectors has a different origin. Today the brand is part of the giant Tyco Electronics conglomerate but when founded in 1941 it was known as Aero-Marine Products.

Another connector maker, Amphenol, was the American Phenolic Corporation, phenol being used for the Bakelite shells of many of their products.

Abbreviations feature in the names of many electronic connector designs and from Europe we have DIN and SCART, both named after the committees that designed them. DIN is the Deutsche Industrie Normenausschuss (German Industrial Standards Committee), whilst SCART or Peritel connectors recalls Syndicat des Constructeurs d'Appareils de Radio et de Télévision (Radio and Television Equipment Manufacturers' Association).

Coaxial Connectordom

Coaxial connectors have names that are shorter but no less abstruse. The UHF connector once widely used by CB and amateur radio enthusiasts is also known as an F&E, in Europe as a PL-type and in Japan as an M-type. The name UHF is confusing as it recalls the connector's wartime radar use at ultra high frequencies, whilst F&E (Films and Equipment Ltd) made many kinds of connector, not just this one (they later became Cannon UK Ltd, by the way).

The N connector is the Neill or Navy type, originated in 1942 by Paul Neill of Bell Labs and standardised on a Navy Bureau of Ships drawing. C-type connectors recall the name of developer Carl Concelman of Amphenol. Mix the two and you get BNC, standing for Baby (or Bayonet) Neill Concelman. This was a baby-size combination of the designs of Neill and Concelman.

EIAJ connectors were devised by the Electronics Industry Association of Japan, whilst MUSA plugs, still used in television studios, recall those originally used for rapid changing of antenna feeders on a pre-war transatlantic radiotelephone project, the Multiple Unit Steerable Array. Not many people know that!

Generic Terms

Tannoy is effectively a generic name for any kind of public address equipment but its makers entered this business entirely by accident. Originally they produced mains power supplies for battery radio sets. A special tantalum alloy was used as the rectifier, hence the trade name.

You can probably guess what kind of product The Automatic Coilwinder Company made but when they introduced a new multimeter that measured amps, volts and ohms all with the same instrument, they coined the slogan AVO. The rest is history and for some people any make of multimeter is an "AVO" to them.

Export Variants

Some products assumed different names when produced for export. British audio valves made by GEC were called Genalex in the USA and Ever Ready batteries sold outside the United Kingdom took on the name BEREC (standing for British Ever Ready Company). In both cases this was to avoid confusion with names already established overseas by the American General Electric and Eveready (one word, not two!) companies. Presumably to avoid similar kinds of confusion European-made Philips products were sold in the USA as Norelco.

Do I detect your eyes glazing over with boredom? Should I stop now? Yes, because I've nearly overshot the word count for this page. But if you know the origins of any other names (or think I've got any of these wrong), please write or email and tell us!

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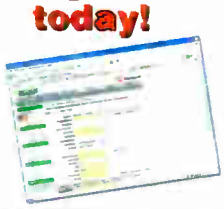

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INTERFACE

Robert Penfold

PC INTERFACING SOFTWARE

IN this month's *Interface* article we will consider the software side of PC interfacing, which is something that seems to be problematic for many readers.

Matters were easier in the days of the GW BASIC and Q BASIC interpreters. One or other of these was supplied as part of the MS-DOS operating system, and they provided a simple but reasonably effective way of writing programs for use with PC electronic projects. The Quick BASIC compiler was available at reasonably low cost, and enabled faster stand-alone programs to be compiled.

Things became more difficult when MS-DOS became obsolete, because Windows 95 and later versions of Windows were not supplied with any form of BASIC. It was necessary to buy a programming language such as Visual BASIC. On the face of it, Visual BASIC is ideal for writing the software for do-it-yourself computer projects. The visual approach makes it easy to produce good virtual controls, meters, or whatever. The standard BASIC functions, arrays, and so on are still there, making it fairly straightforward to manipulate data.

The problem with Visual BASIC is that it has no built-in means of directly accessing the ports. In GW/Q BASIC this was handled by the INP and OUT instructions, as it is in many other computer languages. This shortcoming was solved by Jan Axelson's excellent **Inpout32.dll**, which is suitable for use with Windows 95/98/ME. This is still available at no cost from Jan's web site (**www.lvr.com**).

Another version of **Inpout32.dll** is also available from the Logix4u web site (**www.logix4u.net/inpout32.htm**), and this works with versions of Windows up to Windows XP. This site also has a 64-bit version for use with 64-bit versions of Windows.

Details of using **Inpout32.dll** have been provided several times before in *Interface* articles, and the same ground will not be covered again here. Anyway, both versions are supplied complete with instructions, and further information is provided on the relevant web sites.

Progress?

Visual BASIC 6 plus an add-on to enable it to control the ports is just about the ideal combination for writing software for PC projects. Unfortunately, things move on and Visual BASIC 6 was superseded by Visual BASIC Net, which was a much more powerful program than its predecessor, but was not well suited to writing relatively simple programs, which had always been one of Visual BASIC's selling points. In fact, the new version did not seem to be well suited to most of the areas of programming where its predecessor had excelled.

Microsoft responded to the widespread criticism of Visual BASIC Net by developing a new version, aided by feedback from users. This version is now available in the form of Visual BASIC 2005, and there is a version for hobbyists called Visual BASIC 2005 Express Edition.

It is debatable whether this program is really the equal of Visual BASIC 6 for applications such as control programs for computer hardware projects. It does, however, have one huge advantage though, which is that it is available as a free download from the Microsoft web site!

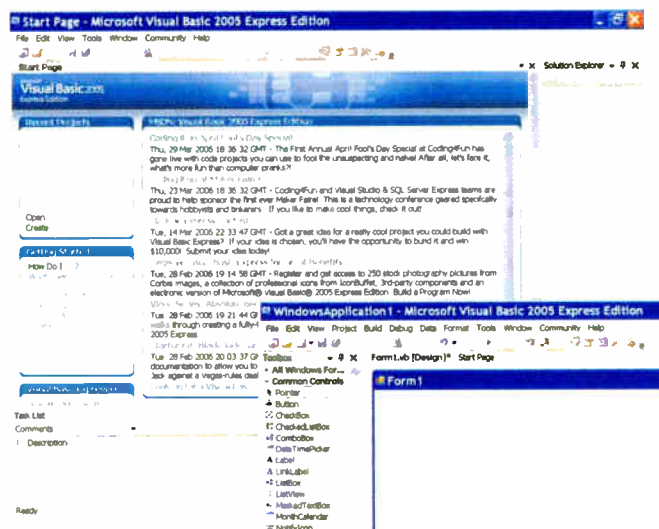

Fig.1. (Left) Initially the program looks a bit gimmicky, with a page that gives the latest news about Visual BASIC 2005 Express Edition

A Beta version of Visual BASIC 2005 Express Edition was covered in previous *Interface* articles. At the time, this was an interesting freebie, but being a beta version it was not totally reliable, or even complete. The current version is the fully finished product. As such it should be fully functional and have good reliability.

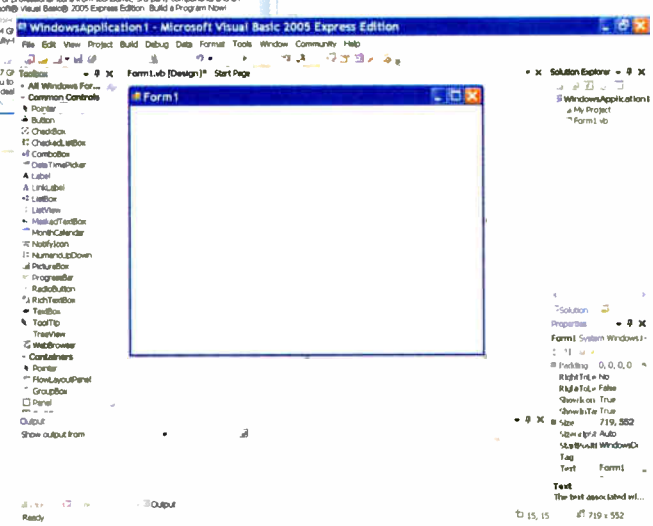

Fig.2. The program has something close to the traditional Visual BASIC look once it is properly "up and running"

One slight drawback is that the size of the download is around 450 megabytes. With a broadband connection of some kind it should only take an hour or two to download, but it could take more like a day or two using a 56k dialup connection. This is the page on the Microsoft site that deals with the program:

http://msdn.microsoft.com/vstudio/express/vb/

This page has some general information about the program and a link to the download page. There is a choice of downloading a small setup program which is then used to download and install the main program, or downloading the main program itself as an image or ISO file. This file is burned to a CD-ROM and then used to install the program in the normal fashion.

The CD-ROM method is probably the best approach since it avoids the need to download the file again if it should be necessary to reinstall the program. It also makes it easy to install the program on several PCs, which is allowed under the licensing conditions.

The program does not really look much like Visual BASIC 6 once it has been installed and run (Fig.1). Assuming there is an active Internet connection, the main panel provides the latest news about Visual BASIC Express Edition. This disappears when you start using the program in earnest (Fig.2.).

The Toolbox that gives access to components such as control buttons, labels, etc. is conspicuously absent. However, it can be activated by selecting Toolbox from the View menu. It is then possible to select objects and place them on the form in the usual way. Adding the Toolbox gives a screen layout that is not too far removed from the one traditionally used for Visual BASIC.

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Upgrading

With the beta version of the Visual BASIC Express Edition it was not possible to modify a Visual BASIC 6 program by loading it directly in the normal way. Instead, it was necessary to go through a simple conversion process. In Microsoft's terminology the program had to be upgraded. This remains the case with the final version of the program. As before, it is just a matter of selecting Open Project from the file menu, and selecting the appropriate file. Trying to open a Visual BASIC 6 project results in the Visual BASIC Upgrade Wizard automatically appearing (Fig.3).

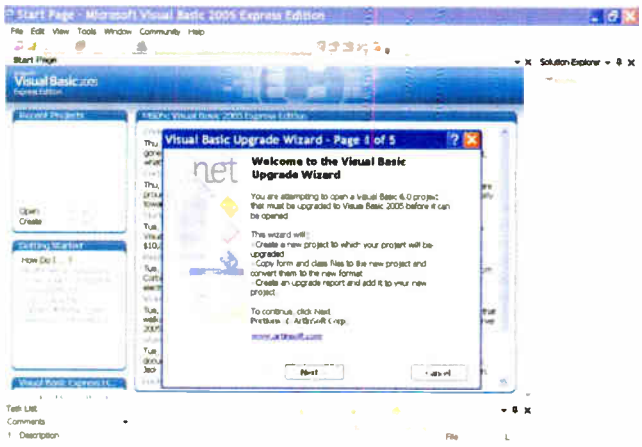

Fig.3. Trying to load a Visual BASIC 6 program results in the Upgrade Wizard being launched automatically

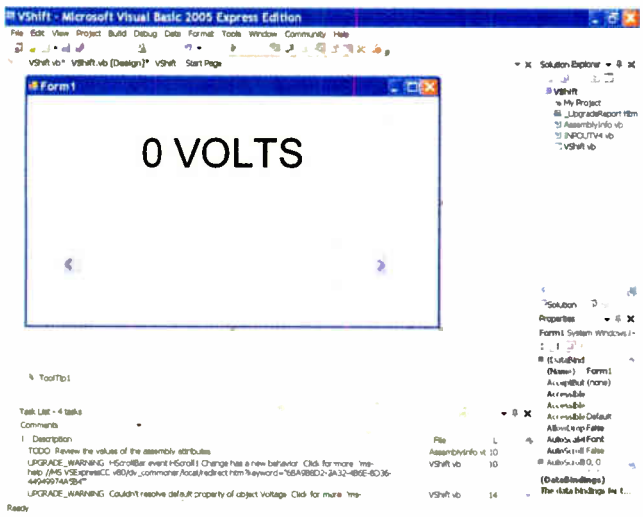

Fig.4. A Visual BASIC 6 program has been successfully upgraded and loaded. It can now be modified, debugged, saved, compiled, etc

When upgrading a simple program it is likely that the wizard will offer few options, if any. However, if given the choice, make sure that an EXE project is selected and not a DLL type.

Upgrading a very simple project that used **Inpout32.dll** proved to be successful (Fig.4), although there were some warning messages added into the code. Strangely, these related to the scrollbar and the label components and not to **Inpout32.dll**. The program compiled without any problems, and almost ran properly. For some reason the label component was not always large enough to take the text in a single line, causing it to wrap onto a second line. Simply making the label a little wider and recompiling the program cured this problem (Fig.5).

In order to write programs that use **Inpout32.dll** it is not enough to have it available to the system. The file with a BAS extension that is supplied with **Inpout32.dll** must be loaded into Visual BASIC so that the INP and OUT instructions are added to its repertoire.

The problem with the beta version of Visual BASIC Express Edition, and the final version, is that there is no apparent means of loading the BAS file. There is no Add File option in any of the menus. An Open File option is available in the File menu, but this does not load the file in the correct manner. Neither does the Add Existing Item in the Project menu.

It is possible to work around the problem by producing a dummy program in Visual BASIC 6 that has the BAS file loaded, but is otherwise empty. This file can be loaded into Visual BASIC 2005 Express Edition and upgraded in the usual way. It then provides a starting point that has **Inpout32.dll** preloaded, with the INP and OUT instructions fully operational.

DIY Project Menu

The upgrade process seems to add a module that makes the new commands operational. An alternative to the rigmarole of the upgrade process is to simply add this module yourself. This is done by going to the Project menu and selecting the Add Module option. A pop-up window is then used to provide a name for the new module, or the default can be accepted. The following code is then entered for the module:

```
Option Strict Off
Option Explicit On
Module inpout

Public Declare Function Inp Lib "inpout32.dll" Alias "Inp32" (ByVal PortAddress As Short) As Short
    Public Declare Sub Out Lib "inpout32.dll" Alias "Out32" (ByVal PortAddress As Short, ByVal Value As Short)
End Module
```

The INP and OUT commands should then work correctly provided **Inpout32.dll** is available to the system. If everything is all right, the usual hint text will appear when you are entering an INP or OUT instruction. The hint text will not appear if something is not quite right, and the word INP or OUT will be underlined to show that it has not been recognised.

The module can be saved by right-clicking its tab and selecting the Save option from the pop-up menu. It will be saved under whatever name you used, plus a "vb" extension. In order to use the INP and OUT commands in the future it is just a matter of starting a new project and then adding the module to it. This is done by selecting Add Existing Item from the Project menu, and using the file browser to find and open the correct module file. Do not use the Open File option in the File menu. This will load the module's file, but not in a way that will produce the desired result.

Finally

Visual BASIC Express Edition inevitably has some omissions compared to the standard product, although it is likely that many of the missing facilities would be of little use in the current context. It does include a potentially very useful SerialPort component, although it is something that has been added to Visual BASIC a bit late in the day. Serial ports are currently being phased out, although many PCs still have at least one of them.

Two regrettable omissions are the Line and Shape components of Visual BASIC 6. These make it easy to draw on-screen circles, lines, and ellipses when producing virtual meters, switches, rotary controls, and so on. They also make it easy to control these objects, so that a meter can be made to produce the correct reading for example. It is still possible to produce these objects with Visual BASIC Express Edition, but it seems to be a matter of resorting to the old fashioned method of normal program code. This is usually much slower than using the visual method to get the basic elements in place, with some "fine tuning" the co-ordinates then being applied if necessary.

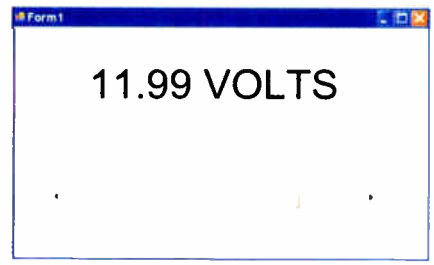

Fig.5. With the label component made slightly wider, the compiled program ran properly

Anyway, Visual BASIC 2005 Express Edition is a step forward from the previous free versions of Visual BASIC in that it does have the ability to compile programs which can then run independently. It is certainly a very worthwhile download for those who do not already own a full retail version of Visual BASIC. It should also be of interest to owners of older retail versions of Visual BASIC such as versions 5 and 6, although it might not be a viable replacement for them.

Express News

Delving into the pricing of VB 2005 Express Edition, it seems that it is free provided it is downloaded before the 6th November 2006. Thereafter it will cost $49 US. Unlike previous low-cost versions of VB, it can be used to produce commercial software.

World Radio History

Widgy

Distortion effects for

Do you own a guitar but don't have an overdrive (or distortion or fuzz) box yet? Well your prayers have been answered! This one sounds great, it's cheap and it's easy to build!

By PETER SMITH

IF YOU'RE A GUITAR PLAYER, then you'll certainly know all about the various "effects" that can be used to enhance guitar sounds. Over the years, many great players have combined these effects with their own unique styles to create unmistakable signature sounds.

Some of the most sought-after sounds are produced by deliberate harmonic distortion of the music content. Originally, this type of effect was produced exclusively by over-driving the output stage of valve amplifiers.

About overdrive & distortion

These days, distortion effects are generated by dedicated electronics equipment. Perhaps in an attempt to capitalise on the success of past legends more than anything, much of this equipment boasts valve-like distortion qualities.

Valve amplifiers have a reputation for soft-clipping the output signal when they are overdriven, at least at moderate levels. If the signal is a pure sinewave, the peaks are simply rounded off, with a certain amount of wave shape compression occurring.

These rounded peaks create predominantly lower-order harmonics. Essentially, this means that the harmonics are closely related to the fundamentals and therefore tend to sound quite natural. Perhaps we could say that they "resonate" or "ring" with the fundamental tones.

Harmonics, by the way, are referred to as "partials" in the music world. They are simply some multiple of the original, fundamental frequencies.

Once the input to any amplifier is increased well beyond its design limit, the output signal is either hard clipped or transformed into indistinguishable noise, depending on the amplifier's overload characteristics.

Unlike the rounded peaks of a soft-clipped waveform, hard clipping is characterised by flat, sharp-edged waveforms. This is due to the output stages driving all the way to the power supply rails, slicing the peaks off and compressing, or "crunching", the signal.

Hard clipping results in many higher-order harmonics of the fundamentals. The resulting sound is often described as "reedy", "rather harsh" and "more metallic".

A side effect called "intermodulation distortion" occurs when all these harmonics inevitably mix. The product of two frequencies is both the sum and difference of the originals, and they may not necessarily be "musically" related to the content. Therefore, intermodulation distortion is unwanted noise that is quite easily detected by the ear.

Ideal distortion?

As far as we can discern, there is no easy way of generating the ideal distortion effect. Why? Primarily

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Box

our guitar

because it would be impossible to get broad agreement on what that sound is. It has more to do with music type, personal preference and playing styles than the pure technicalities.

Many commercial distortion effects units combine both soft and hard clipping and user-accessible controls are included to provide adjustment between these two extremities, thus accommodating a range of music and styles. Some also include tone controls for increased versatility.

The *EPE* "WidgyBox" (like the name?) is based on these ideas. The design criterion was simple: it had to be uncomplicated, low-cost and easy to build. We think it will make a worthwhile addition to any guitarist's basic effects line-up.

Reproducing the sound

Now for the $64,000 question: if valve amplifiers already produce the desired sound, then why bother trying to reproduce it? Why not just use a valve amplifier?

Well for a start, valve amplifiers are expensive. In addition, they need to be over-driven to produce the effect. This means lots of volume, which can obviously be a real problem. In the words of one disaffected player, "I have good tone when I play loud but I get kicked out of clubs and bands".

MAIN FEATURES

- Low cost.
- Easy to build.
- Battery-powered.
- Adjustable distortion.
- Three tone controls.
- Optional stomp switch.

Dedicated effects boxes (also known as "effects pedals" and "stomp boxes") address these issues. They create the desired effect before the amplifier input, allowing the musician to play at any volume. They also allow easy experimentation for those in search of a unique sound. What's more, you don't need a valve amplifier – a (much) cheaper solid-state amplifier will suffice!

How it works

Fig.1 shows the details of our design – it's based entirely around the TL07x series op amps. Like most effects pedals, the circuit is designed to connect directly in-line with the guitar's output.

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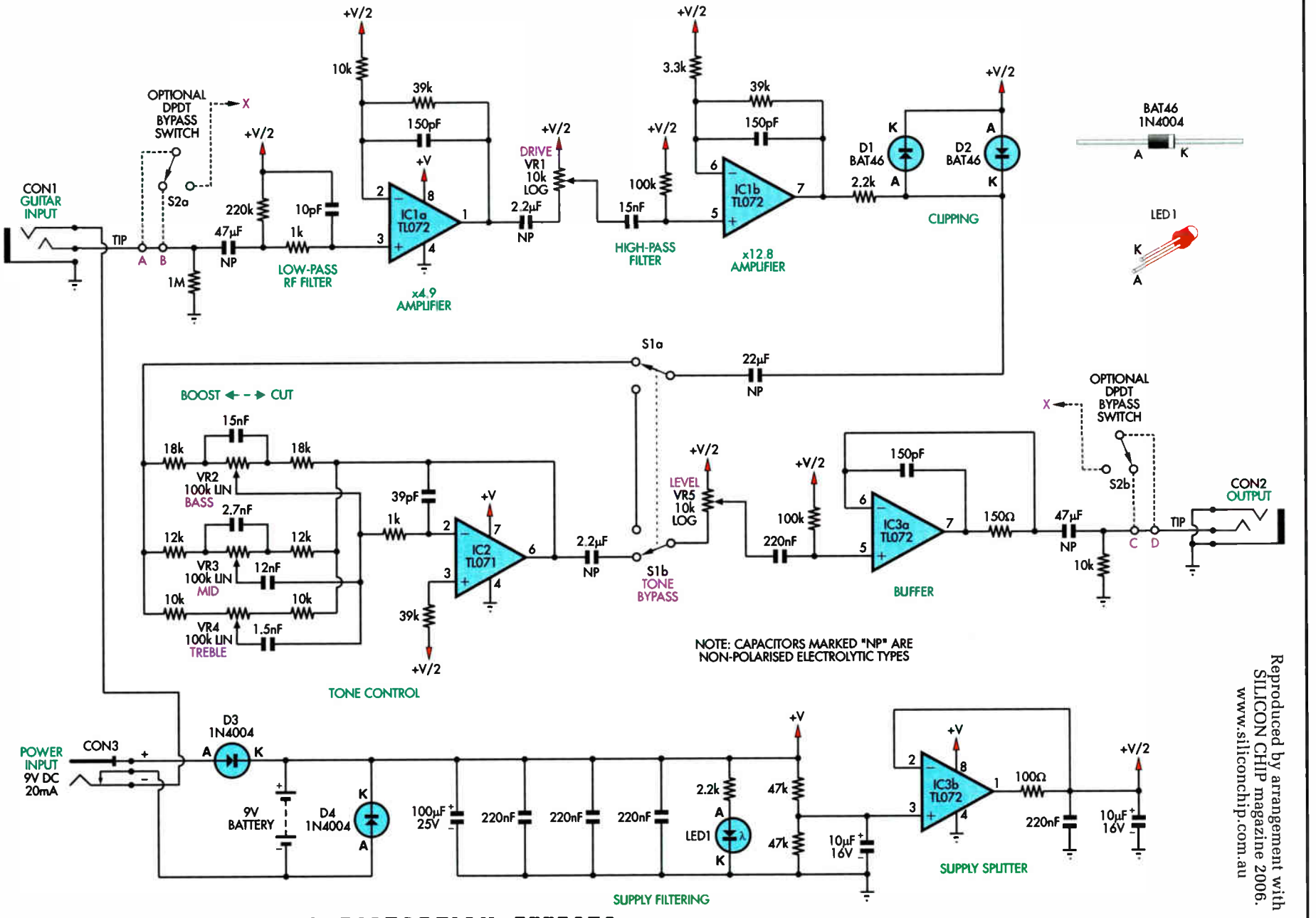

"WIDGYBOX" GUITAR DISTORTION EFFECTS

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Fig.1: the circuit uses three low-cost op amps (IC1-IC3) and operates from a 9V battery. Schottky diodes D1 & D2 provide the soft clipping function, while IC1b provides hard clipping, depending on the setting of VR1.

Effects Bypassing: The Different Methods

Generally, it's desirable to be able to switch effects in and out during a performance. A popular means of doing this is via a foot switch built into the same box that houses the electronics. This arrangement is part of all commercial effects pedals.

Another common method relies on a dedicated bypass box, which is simply wired in series with the effects input and output leads.

In the latter approach, the bypass function physically switches the effects box out of the signal path. This is termed "hard" bypassing, as opposed to "soft" bypassing, where some part of the effects electronics is still in-circuit (usually an input buffer and/or line driver).

"Hard" bypassing is a popular approach because it ensures that the effect has no impact whatsoever on the signal, especially in relation to loading or otherwise distorting the signal source. A good example of a do-it-yourself bypass box can be found on the web at **www.geofex.com/Article_Folders/Millenium/millen.htm**

Alternatively, the WidgyBox has provision for an internal DPDT "hard" bypass switch. It's simply a matter of removing the two wire links adjacent to the input and output sockets and wiring up switch S2 as shown on the circuit diagram (Fig.1).

We envisage an internal switch being used in conjunction with a more robust ("stomp proof") metal case!

A 47µF capacitor AC-couples the input to the first op amp stage (IC1a). This capacitor is much larger than you might expect in order to ensure low noise performance. As with all the following stages, IC1a's input is biased to one-half the supply rail voltage (+V/2), in this case via a 220kΩ resistor. The 1kΩ resistor and 10pF capacitor at the input act as a low-pass filter, preventing RF (radio frequency) signals from being coupled into the circuit.

IC1a is wired in a non-inverting configuration with a gain of 4.9, as set by the 39kΩ and 10kΩ feedback resistors. The 150pF capacitor in the feedback path rolls off the frequency response above the audio spectrum.

IC1a's output appears at pin 1 and is coupled via a 2·2µF capacitor to Drive pot VR1. This pot controls the signal level into the next stage, for reasons that will become clearer shortly.

The signal from the VR1's wiper is in turn AC-coupled to op amp IC1b via a 15nF capacitor. This capacitor also acts with a 100kΩ bias resistor to form a high-pass filter, to provide a small measure of pre-distortion equalisation. This is necessary to reduce the effects of harmonics from the lower strings. Apparently, these low frequency harmonics tend to sound a little "fruity" during chord work.

In addition, cutting the low end response may also help with guitar pickup equalisation.

IC1b is configured as a non-inverting stage and operates with a gain of 12.8. It has two important roles, the first being to drive a pair of back-to-back diodes (D1 & D2) whose job it is to perform the soft clipping function.

Clip job

The way that this works is quite straightforward. Once the peak signal level exceeds the forward voltage (0·2–0·4V) of the diodes, they start to conduct, thus clipping the highs and lows off the waveform. In addition, the non-linear conduction characteristic of the diodes give the peaks a smooth, rounded appearance.

Regardless of increasing drive level, the diodes continue to clip the signal to about the same voltage, resulting in even more waveform compression (and distortion).

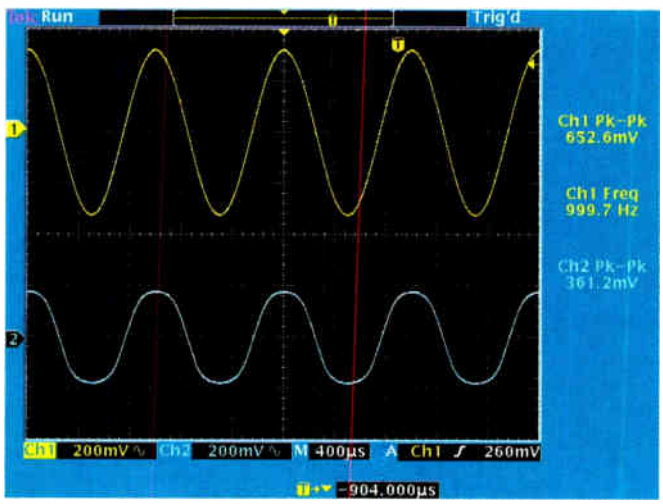

Fig.2: moderate soft clipping. The top waveform shows the signal into op amp IC1b, while the bottom waveform shows the signal across the clipping diodes (D1 & D2). Note the smooth waveform peaks. Compression is already quite noticeable, nearing a 2:1 ratio.

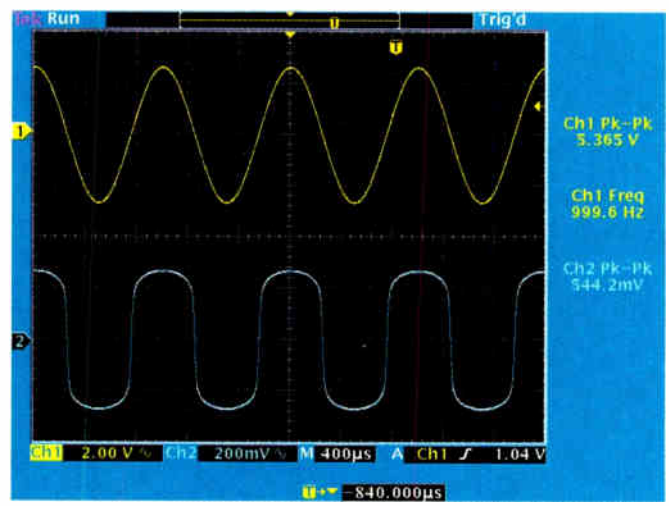

Fig.3: this is the maximum soft clipping signal, again taken across diodes D1 & D2. Note that the rising and trailing edges are almost vertical now but we still have rounded peaks. The compression is now quite high and this also imparts quite a degree of sustain.

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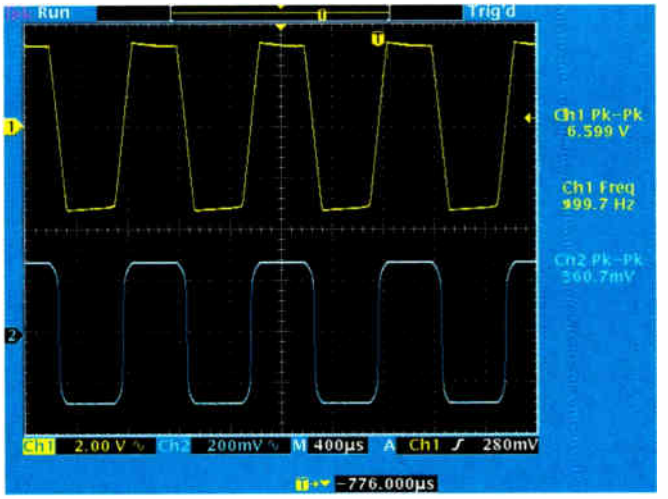


Fig.4: maximum hard (and soft) clipping. The top waveform shows the hard-clipped op amp output. At the bottom, we can see what it looks like across the diodes. The amplitude isn't much different to Fig.3 but the peaks have been "flattened".

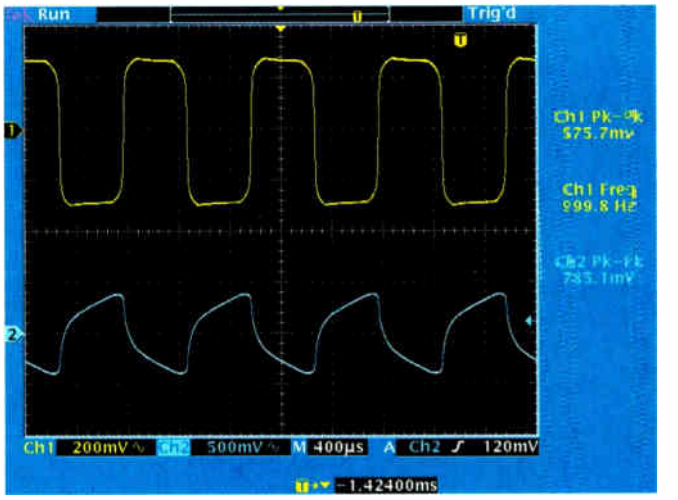


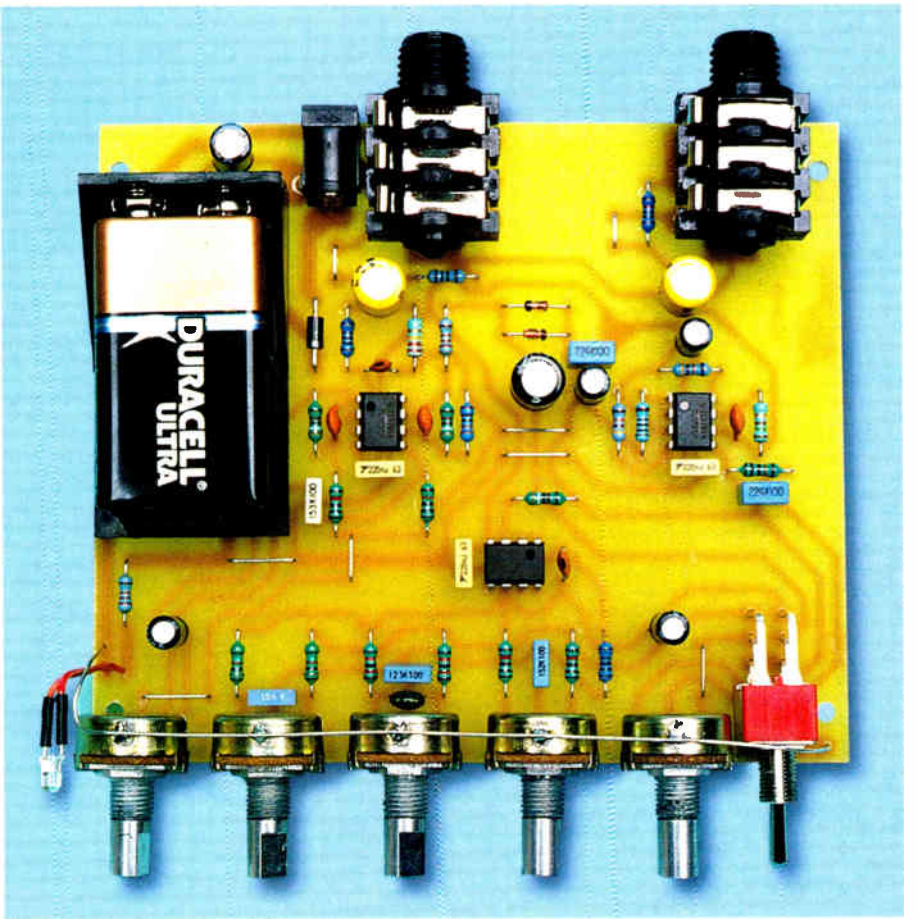
Fig.5: fiddling with the tone controls has a bigger effect than you might expect, because it's boosting or cutting the harmonics as well. Here's what the output of the box looks like (bottom waveform) when we wind up the bass boost.

At very high drive levels, IC1b's second role comes into play – it starts to hard clip the signal. What happens is that the amplified signal level exceeds the op amp's maximum available output swing – so it is abruptly clipped.

This is normal behaviour for any over-driven op amp and it's exactly what we need for our hard clipping function!

As a matter of interest, the TL072 clips non-symmetrically. This suggests that not only do we get the higher-order harmonics mentioned earlier but also a larger proportion of even rather than odd multiples.

Note that we've specified Schottky diodes for D1 & D2 as they have a lower forward voltage than the common 1N4148/1N914 varieties. This gives a larger adjustment range between soft and hard clipping, allowing more waveform compression and increasing the "sustain" effect.



This close-up view shows the final version of the PC board. Take care to ensure that all polarised parts are installed the right way around.

Tone controls

The distorted signal is routed to a Baxandall type tone control network, based around op amp IC2 and potentiometers VR2, VR3 & VR4.

These pots and their associated resistors and capacitors form the feedback network between the op amp's inverting input and its output.

Each of the bass, mid and treble networks can be considered separately since they are connected in parallel between the signal input following IC1b and the output of IC2 at pin 6. Furthermore, the wiper of each pot is effectively connected to the inverting input (pin 2) which is a virtual ground.

Operation of the bass control is as follows: with VR2 centred, the value of resistance connected between the output from IC1b and pin 2 of IC2 is the same as that between pins 2 & 6 and this sets the gain to -1. The 15nF capacitor has no effect since it is equally balanced across the potentiometer.

If we move the wiper of VR2 to the full boost position (ie, rotate the pot

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Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
220nF	0·22µF	220n	224
100nF	0·1µF	100n	104
15nF	0·015µF	15n	153
12nF	0·012µF	12n	123
2.7nF	0·0027µF	2n7	272
1.5nF	0·0015µF	1n5	152
150pF	150pF	150p	150
39pF	39pF	39p	39
10pF	10pF	10p	10

shaft fully clockwise), we get 19kΩ (18kΩ + 1kΩ) between the input and pin 2 of IC2 and 119kΩ between pins 2 & 6. In addition, the 15nF capacitor is across the 100kΩ resistance in the feedback loop.

Without the capacitor the gain would be -119kΩ/19kΩ or -6.3 at all frequencies. But with the capacitor, the gain is high only at around 50Hz and as the frequency rises it comes back to -1 (ie, overall unity gain). Thus we have bass boost.

Conversely, when VR2 is wound fully anticlockwise, the position is reversed and we get a gain of 19kΩ/119kΩ or -0.16 (-16dB). The capacitor is now on the input side and provides less gain at frequencies below 100Hz but with gain increasing to -1 at frequencies above 100Hz. Thus we have bass cut. Various settings of VR2 between these two extremes will provide for less boost and cut.

The midrange section works in a similar manner except that there is now a 12nF capacitor between VR3's wiper and pin 2. This, along with the 2·7nF capacitor across VR3, gives a bandpass filter, so we either boost or cut the midrange frequencies.

The treble control operates with no capacitor across VR4 but has a 1·5nF capacitor between its wiper and pin 2 to produce a high-frequency boost or cut at 10kHz. A 39pF capacitor between pins 2 & 6 of IC2 provides a high-frequency rolloff to prevent oscillation which could otherwise occur when

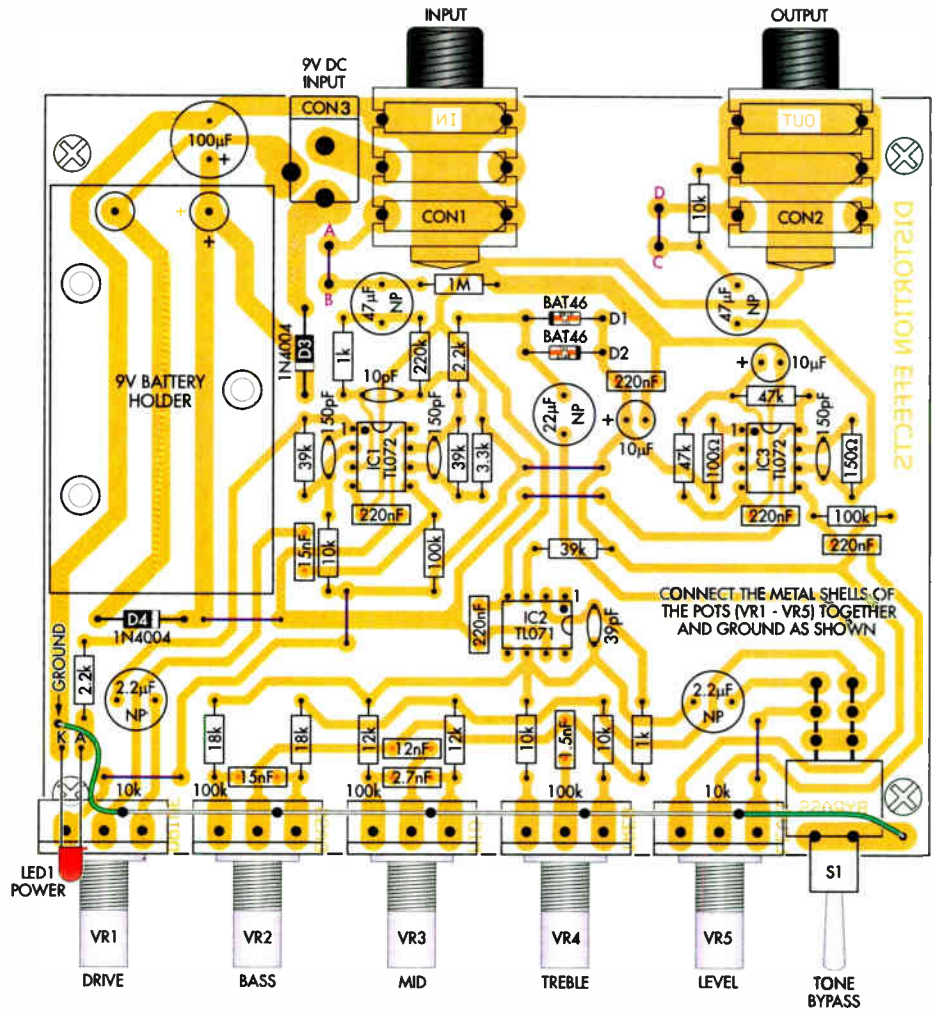

Fig.6: here's how to install the parts on the PC board. Install the smaller parts first before moving on to the output sockets, the battery holder and (finally) the pots (see text).

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	220kΩ	red red yellow brown	red red black orange brown
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	2	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	3	39kΩ	orange white orange brown	orange white black red brown
❑	2	18kΩ	brown grey orange brown	brown grey black red brown
❑	2	12kΩ	brown red orange brown	brown red black red brown
❑	3	10kΩ	brown black orange brown	brown black black red brown
❑	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown

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Parts List

1 PC board coded 573, available from the *EPE PCB Service*, 117mm x 100·5mm
1 110 x 140 x 35mm (L x W x H) plastic instrument case
1 DPDT PC mount toggle switch (S1)
2 6·5mm PC-mount stereo switched sockets (CON1 - CON2)
1 2·1mm PC mount DC socket (CON3)
1 9V PC mount battery holder
3 100kΩ 16mm PC mount linear pots (VR2 - VR4)
2 10kΩ 16mm PC-mount log pots (VR1, VR5)
5 knobs to suit pots
20mm length of small heatshrink tubing
70mm length of light duty hook-up wire
320mm length of 0.71mm tinned copper wire

Semiconductors
2 TL072CP dual op amps (IC1,IC3)
1 TL071CP op amp IC (IC2)
1 3mm high-brightness red LED (LED1)
2 BAT43 schottky diodes (D1,D2)
2 1N4004 1A silicon diode (D3,D4)

Capacitors
1 100µF 25V PC electrolytic
2 10µF 16V PC electrolytic
2 47µF 16V non-polarised PC electrolytic
1 22µF 16V non-polarised PC electrolytic
2 2·2µF 16V non-polarised PC electrolytic
5 220nF (0·22µF) 50V MKT polyester
2 15nF (0·015µF) 50V MKT polyester
1 12nF (0·012µF) 50V MKT polyester
1 2·7nF (0·0027µF) 50V MKT polyester
1 1·5nF (0·0015µF) 50V MKT polyester
3 150pF 50V ceramic disc
1 39pF 50V ceramic disc
1 10pF 50V ceramic disc

Resistors (0·25W, 1%)

1 1MΩ	3 10kΩ
1 220kΩ	1 3.3kΩ
2 100kΩ	2 2.2kΩ
2 47kΩ	2 1kΩ
3 39kΩ	1 150Ω
2 18kΩ	1 100Ω
2 12kΩ	

the treble control is set for maximum boost. Similarly, the 1kΩ resistor in series with pin 2 is there to attenuate RF signals; it stops radio breakthrough.

Being able to boost or cut the distorted signal in three distinct bands gives you a lot of control over your sound – more, in fact, than is possible with many commercial units, which commonly provide only one or two bands of adjustment.

Switch S1 has been included to allow you to quickly bypass the tone circuitry altogether should you wish to control it elsewhere in your setup.

Level control & output

IC2's output is AC-coupled via a 2·2µF capacitor to VR5. This pot allows you to set the output level to match the input, thus preventing any noticeable jump in volume when the WidgyBox is switched in and out (see the panel entitled "Effects Bypassing: The Different Methods"). From there, the signal is AC-coupled via a 220nF capacitor to op amp IC3a. This op amp is configured as a voltage follower – it simply buffers the incoming signal and passes it through unchanged.

A 150Ω resistor decouples IC3a's output from any cable capacitance, thereby ensuring stability under all conditions. This is followed with a 47µF capacitor to remove the DC offset. Finally, a 10kΩ resistor terminates the output to ground, ensuring that there are no nasty clicks when the box is hot-switched into the signal path.

Power supply

In keeping with other popular effects pedals, power for the unit is provided by a 9V alkaline battery. The current drain is only about 12-15mA, so you'll get more than a days' continuous use and many days of intermittent use before a swap is required.

Alternatively, power can be provided by a 9V DC plugpack. Be aware,

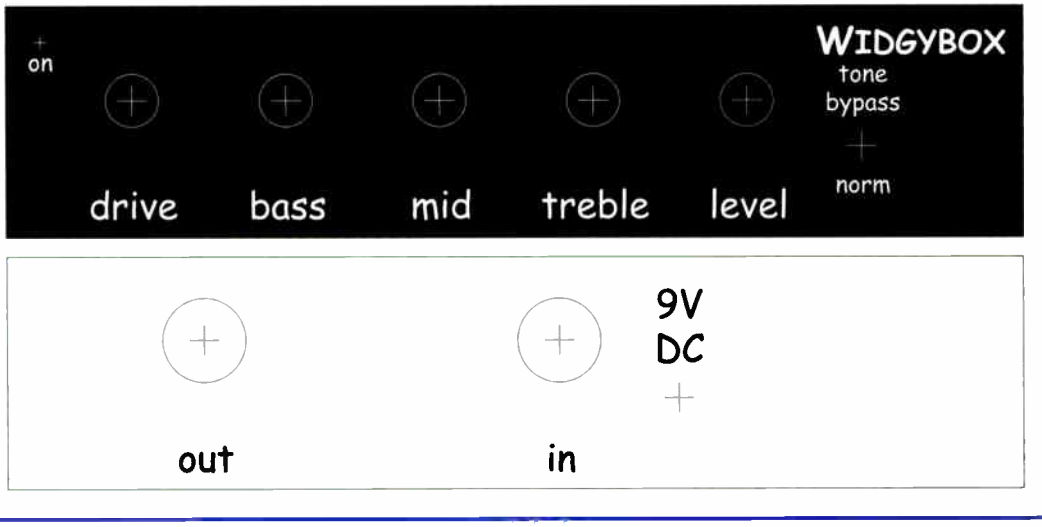

Fig.7: these full-size artworks can be used as drilling templates for the front and rear panels. Drill small pilot holes to begin with, then carefully enlarge each hole to size using a tapered reamer.

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though, that most unregulated plugpacks put out much more voltage than their rating at these low current levels.

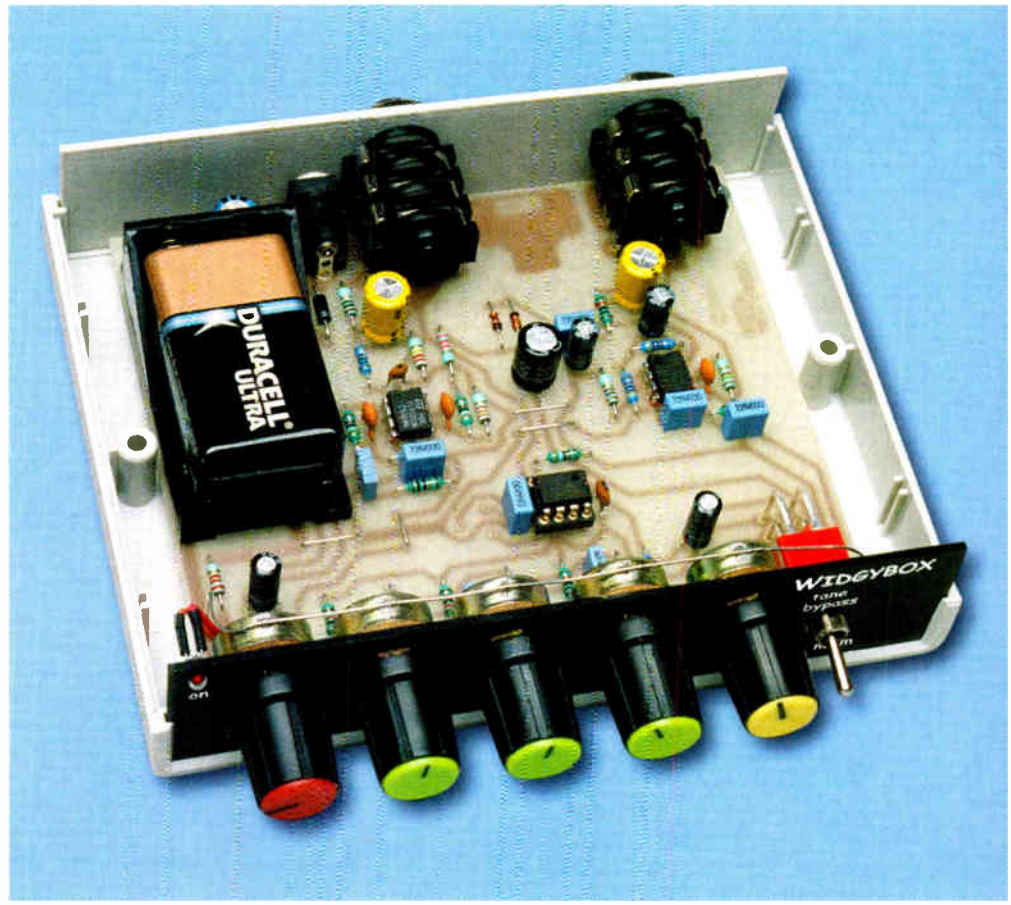
Although this won't damage your box, the higher voltage will alter the characteristics of the distortion effects at high drive settings.

If you have a plugpack with selectable output voltages, you may find that the 7·5V setting provides about 9.5V under light load, which is ideal.

Note that the negative terminal of the battery connects to earth via the switch contacts of the DC input socket (CON3) and the middle and common contacts of the guitar input socket (CON1). This means that you'll need to plug in your guitar to power up the box.

It also means that when a plugpack jack is inserted, the battery is disconnected. This feature is very important, otherwise the plugpack would attempt to charge the battery and that could have loud and startling consequences!

Finally, the half supply voltage rail (ie, +V/2) needed by all of the bias networks is generated by op amp IC3b and its associated circuitry. Two 47kΩ resistors divide the +V rail in half, after which it is filtered by a 10µF capacitor and then buffered by op amp IC3b. A 100Ω resistor in series with IC3b's output decouples the large 10µF filter capacitor.



The assembled PC board fits neatly into a low-profile plastic instrument case. Note that the PC board shown here is a prototype version and differs slightly from the final version shown in Fig.6.

Construction

With the exception of the power LED, all components mount on a single PC board, coded 573.

Using the overlay diagram in Fig.6 as a guide, begin by installing the eight wire links using 0·7mm tinned copper wire or similar. Note that the two links adjacent to the input and output sockets (CON1 & CON2) can be left out if you intend fitting a foot switch to the box but more on that later.

Install the low-profile components first, beginning with the resistors and diodes (D1-D3). Follow with the three op amp ICs (IC1-IC3). Make sure that you have the pin 1 (notched) end of each IC oriented as per the overlay diagram. In addition, note that IC2 is a TL071 (single) op amp, whereas the others are TL072 (dual) versions. Don't mix them up!

The two jack sockets (CON1 & CON2) and the DC socket (CON3) can go in next. When inserting the jack sockets, push them all the way down until the shoulders of all pins make contact with the PC board surface. Follow with the battery holder, which should be secured to the PC board with No. 4 × 6mm self-tapping screws prior to soldering.

Next, install all the capacitors. The 100µF and two 10µF electrolytic capacitors are polarised and must go in the right way around. The remaining five electrolytics are non-polarised (marked "NP" on the overlay) and can go in either way.

Potentiometers VR1-VR5 and switch S1 should be installed last of all. Start with VR1 but solder its middle pin only. Lift the board to eye level and examine the position of the pot from the front and side. It should be sitting perfectly "square".

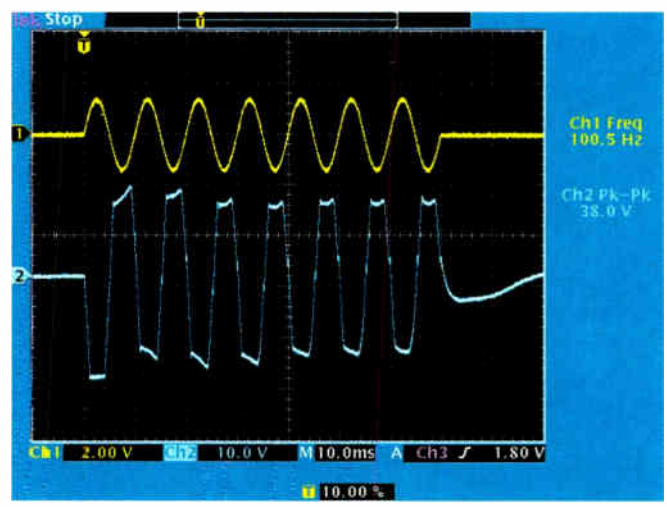


Fig.8: having heard all the stories about valve distortion, we were consumed with curiosity and had to have a look at it ourselves. A kind gentleman loaned us his valve guitar amplifier and we captured this waveform when it was overdriven. That doesn't look too soft, does it?

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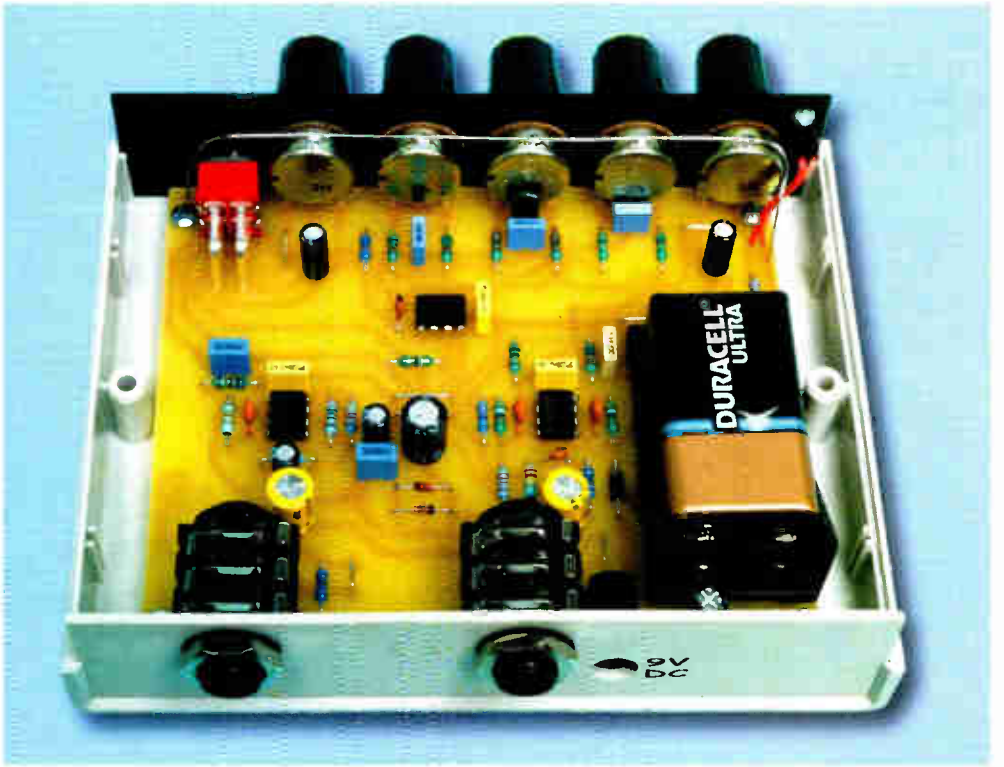

The rear panel carries the 6.5mm stereo switched sockets and includes an access hole for the DC power socket. Note that the PC board in this photo is the final version, as shown in Fig.6.

Why bother? – well, when we eventually fit the front panel, this step helps to ensure that all the pot shafts are aligned, improving appearance and minimising stress on solder joints when the nuts are tightened.

Adjust the pot position as necessary and then solder the remaining two pins. Repeat this procedure for the other four pots.

Finally, install the tone bypass switch (S1), ensuring that it is seated firmly on the PC board surface before soldering.

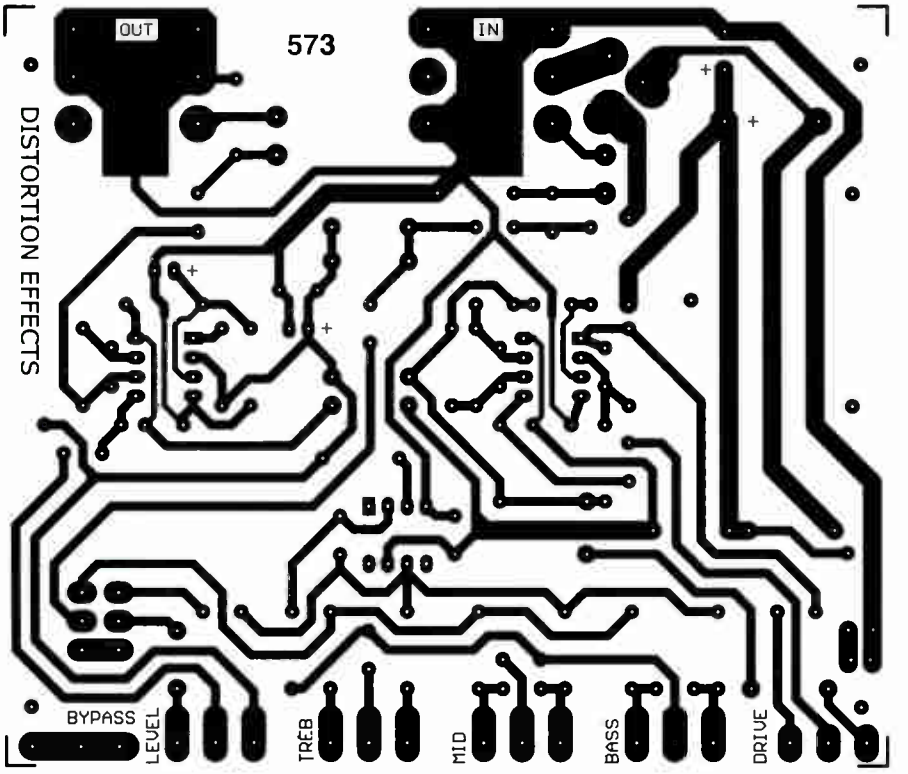

Fig.9: this is the full-size etching pattern for the PC board.

Case preparation

As supplied, the bottom half of the case contains eight mounting posts. The four outermost posts are used to support the PC board, while the four inner posts are not required and must be removed. This can be done using a chisel or an oversized drill bit.

The templates shown in Fig.7 provide the quickest and easiest method of getting all the holes in the right places for the front and rear panels. Photocopy the templates, cut them out and carefully align and tape each one to a blank panel.

First, gently centre-punch the holes directly through the templates, then remove them and drill 1mm pilot holes for each mark. Don't attempt to jump directly to a large diameter drill, as you may split a panel or get the holes off-centre. Instead, drill the holes progressively larger in several steps.

Some constructors won't have fractional drill sizes all the way up to the large diameters of the pot shafts and jack sockets. In this case, a tapered reamer is ideal for enlarging the holes to their final sizes.

Trial fit

The front panel should not be forcibly fitted over the pot shafts. If the holes are correctly sized for the shafts but the panel is still a tight fit (or won't fit!), then the holes are obviously out of alignment. Increase the hole sizes as necessary to get an easy fit. This is quite important; a good fit keeps all the pot shafts in alignment.

With the drilling done, slide the panels into place and loosely install washers and nuts on all the pots and the two jack sockets. The assembly should now slip home in the case bottom without too much trouble. Check that you can sight the four mounting post holes through the PC board holes and that the posts actually make contact with the underside of the board. If all is well, tighten up the nuts by hand.

Grounding the pots

To minimise extraneous noise, the metal shells of the pots must be

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connected to the ground (0V) rail. This is achieved by soldering a single length of tinned copper wire to the metal top of each pot and terminating it to the PC board at either end. The overlay diagram (Fig.6) and the various photos show where to position this wire.

In order to get the solder to adhere to the pots, remove a small spot of the cadmium plating on each pot with an ink rubber or scouring pad and clean the area with alcohol. That done, pre-tin the spot with a fairly hot iron and large gauge multicore solder before attempting to attach the earth wire.

Installing the LED

To mount the LED, first strip and tin the ends of two 30mm lengths of light-duty hook-up wire. That done, shorten the LED leads to about 8mm, solder one end of each wire to a LED lead and insulate the connections with heatshrink tubing.

Finally, slip the LED into position in the front panel and solder the two leads to the PC board as shown in Fig.6. Be sure to install the LED with the correct polarity, though. The flat edge on the LED body goes towards the edge of the case (see Figs.1 & 6).

If necessary, the LED can be fixed in position with a spot of glue or silicone sealant.

Testing

A few quick voltage measurements around the circuit will help to confirm that your project is ready for use. You'll need a fresh 9V battery, a mono jack plug and a multimeter.

Fit the battery and insert the plug in the input socket (CON1). The plug can be on one end of your guitar lead but don't connect anything to the other end just yet!

As soon as the plug is inserted, the power LED should light. If it doesn't, then remove the plug immediately and check the orientation of the LED. Also, check that there is continuity through the DC socket (CON3) switch contacts, which can be identified by tracing the negative connection from the battery.

If the above checks don't identify the problem, then suspect a short or low resistance between the +V rail (battery positive) and ground (battery negative). You may have inadvertently reversed one of the ICs or perhaps there is a solder bridge between tracks somewhere. Follow the +V trace around the board to track it down.

Sound Fun: Experimenting With The Circuit

Like to experiment a little? Then check out these ideas!

As explained in the text, the high-pass filter formed by the 15nF capacitor and 100kΩ resistor at the input of IC1b provides for some pre-distortion equalisation.

The 3dB point of this filter is around 100Hz. A higher or lower point may better suit your system. We suggest an upper limit of about 300Hz (no lower limit). Here are some example values: for a 194Hz 3dB point, use 8·2nF instead of 15nF; for 284Hz, use 5·6nF.

It is also possible to experiment with the distortion-making section of the circuit. For example, replacing one of the Schottky diodes with a common 1N4148 will create non-symmetrical clipping for quite a different sound. You could also substitute germanium diodes, which have softer turn-on characteristics. Have fun!

OK, let's assume your LED lights up. Next, we'll check that power arrives at each op amp IC supply pin.

Set your multimeter to read DC volts and measure between pins 4 & 8 of both IC1 and IC3. That done, repeat this measurement between pins 4 & 7 of IC2. In all cases, the reading should be about 9·2V.

Now touch the negative probe of your meter to the negative battery terminal and the positive probe to pin 2 of IC2. Your reading should be very close to half the voltage measured above (about 4·6V).

Final touches

The next step is to secure the PC board to the case posts with four No. 4 × 6mm self-tapping screws. Before tightening the screws, it's a good idea to temporarily loosen off the pot and jack socket nuts, so that the assembly settles "comfortably" into position.

The final job is to shorten the pot shafts to match the knobs. Before doing this, screw the top half of the case into position and tighten up all of the pot nuts.

The procedure now is to grip the tip of each pot shaft (in turn) in a vice, starting with VR1. You can then carefully cut off the unneeded section of the shaft using a hacksaw. For our prototype, only 14mm of shaft length (measured from the surface of the panel) was required for the push-on type knobs. Be sure to support the weight of the assembly during the cutting.

That's it – your WidgyBox is ready to rock! **EPE**

Help – It Doesn't Work!

Before doing anything else, double-check all component values against the overlay diagram. If that doesn't turn up anything, then some detective work is in order.

If you have no output at all, then a few additional DC voltage measurements may help to narrow the problem down to a particular op amp and/or it's immediate circuitry.

Apply power and wait at least 10 seconds for the bias networks to fully charge. Don't apply a signal to the input or connect anything to the output socket during these checks.

Connect your multimeter's negative probe to battery negative and touch the positive probe to each op amp output in turn (IC1a pin 1, IC1b pin 7, IC2 pin 6 and IC3a pin 7). Although the readings will vary slightly, they should all be close to one-half battery voltage. A large variation in any reading indicates a problem in the immediate vicinity.

Alternatively, if you have output signal but varying the drive pot doesn't change the distortion level, then suspect a problem with the feedback circuitry around IC1a or IC1b.

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£50 - £99.99	£10	£500+	£40
£100 - £199.99	£20		

Max weight 12lb (5kg). Heavier parcels POA. Minimum order £20.

Tempmaster Kit

KC-5413 £11.7S + post and packing NEW FOR '06

Need accurate temperature for a wine cooler or beer brewing heater? This project turns a regular fridge or freezer into a wine cooler by accurately controlling the temperature to make it suitable for wine storage. A much cheaper option than commercial units. Kit supplied with PCB, case, mains plug & all electronic components.

Australian to UK mains adaptor required. Use PP-4020 £2.9S

Theremin Synthesiser Kit

KC-5295 £14.75 + post & packing NEW FOR '06

The Theremin is a strange musical instrument that was invented early last century but is still used today. The Beach Boys' classic hit "Good Vibrations" featured a Theremin. By moving you hand between the antenna and the metal plate, you can create unusual sound effects. Kit includes a machined, silkscreened, and pre-drilled case, circuit board, all electronic components with clear English instructions.

- This product is also available built and fully tested AM-402S £29.9S

Requires 9VDC wall adaptor (Maplin #GS74R £9.99).

Speaker Bass Extender Kit

KC-5411 £6.00 + post & packing

Most audiophiles know that loudspeaker enclosures have a natural frequency rolloff which is inherent in their design. The Bass Extender kit boosts the level of the bass to counteract the natural rolloff of the enclosure, producing rich, natural bass. It gives an extra octave of response, and is sure to please even the most avid audiophiles.

- Kit supplied with PCB, and all electronic components.

Starship Enterprise Door Sound Simulator

KC-5423 £11.7S + post & packing NEW FOR '06

Emulate the unique sound made when the cabin doors on the Starship Enterprise open and close. It can be triggered by switch contacts, which means you can use a reed magnet switch, IR beam or PIR detector.
Kit includes a machined, silkscreened, and pre-drilled case, circuit board, speaker and all electronic components with clear English instructions.

- Power: 9-12VDC.

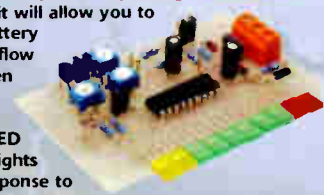
For all you Trekkie fans...

Voltage Monitor Kit

KC-5424 £6.00 + post and packing NEW FOR '06

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features a 10 LED bargraph that lights the LEDs in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges complete with a fast response time, high input impedance and auto dimming for night time driving.
Kit includes PCB with overlay, LED bargraph and all electronic components.

- 12VDC
- Recommended box: UBS HB-601S £0.83



Universal High Energy Ignition Kit

KC-5419 £27.7S + post & packing NEW FOR '06

A high energy 0.9ms spark burns fuel faster and more efficiently to give you more power! This kit can be connected to conventional points twin points or reluctor ignition systems. Kit includes PCB, case and all electronic components with clear English instructions.

Battery Zapper MkII

KC-5427 £29.00 + post & packing NEW FOR '06

The circuit produces short bursts of high level energy to reverse the damaging sulphation effect in wet lead acid cell batteries. This improved unit features a battery health checker with LED indicator, circuit protection against badly sulphated batteries, test points for a DMM and connection for a battery charger. Kit includes a machined, silkscreened, and pre-drilled case, circuit board, alligator clips, all electronic components with clear English instructions. Suitable for 6, 12, and 24V batteries.

Battery Zapper Add-On Kit

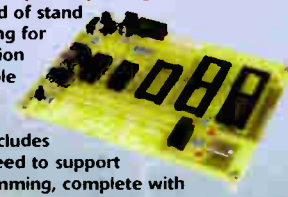
KC-5428 £17.50 + post & packing

If you are one of our customers who purchased the original Battery Zapper Kit, buy this add-on and upgrade your Zapper to the full functionality of the Battery Zapper MKII

AVR Adaptor Board

KC-5421 £10.2S + post & packing NEW FOR '06

A low cost method of stand alone programming for when the application board is unavailable or doesn't include an ISP (or JTAG) header. The kit includes everything you need to support in-system programming, complete with a regulated power supply, clock source and microcontroller IC socket. Designed in conjunction with KC-5420 AVR Serial Programmer (shown below)



AVR ISP Serial Programmer

KC-5340 £14.7S + post & packing

Program, erase and rewrite the program and data memory in your AVR micro-processor without removing it from the application circuit. The kit connects to the serial port, uses royalty free software available on the Internet and allows you to program a multitude of micros in the AVR 8-bit RISC family (see our website for listing). Kit includes PCB, case with silkscreened lid and all electronic components.

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Three Stage FM Transmitter

KJ-8750 £6.50 + post & packing

The circuit board may measure just 70(L) x 17(W)mm, but it can transmit signals over one kilometre in the open. It has flexible power requirements, with 6 to 12VDC input voltage (so a 9V battery would be suitable). It is quick to build, and fun to use.

Kit supplied with circuitboard, electronic components, and clear English instructions.
- Recommended box: UBS HB-6015 £0.83

Remote Control Extender

KC-5209 £7.50 + post & packing

This kit will let you control a DVD or Hi-Fi system using a remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the DVD or other receiving equipment. This kit will work with virtually any remote control system. Kit includes case, silkscreened front panel.
- 2 wire cable required

Requires 9VDC wall adaptor (Maplin #GS74R £9.99).

Video Enhancer/Stabiliser Kit

KC-5390 £31.95 + post & packing

Copy protection is put in place on videos and DVDs for a good reason, but this robs you of the true high quality reproduction they are capable of. This kit supports composite and S-video signals and can be configured for NTSC or PAL format. Kit includes case, circuit board, all electronic components, and clear English instructions. Some SMD soldering required.

Requires 9VAC wall adapter (Maplin #GU09K £9.99).

Caution. During signal conditioning, this unit removes copyright protection. Piracy is a crime and Jaycar Electronics takes no responsibility for its potential for unlawful use.

STOP PRESS STOP PRESS

Over the last few months EPE has been publishing a series of popular kits by Silicon Chip Magazine Australia. These projects are well designed 'bullet proof' and already tested down under. All Jaycar kits are supplied with specified board components, quality fiberglass tinned PCBs and clear English instructions.

Smart Card Reader and Programmer Kit

KC-5361 £15.95 + post and packing

Program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. Card used need to conform to ISO-7816 standards, which includes ones sold by Jaycar. Powered by 9-12 VDC wall adaptor or a 9V battery. Instructions outline software requirements that are freely available on the internet. Kit supplied with PCB, wafer card socket and all electronic components.
PCB measures: 141 x 101mm.
- As published in Everyday Practical Electronics May 2006

Jaycar cannot accept responsibility for the operation of this device, its related software, or its potential to be used in relation to illegal copying of smart cards in cable TV set top boxes.

Gold Wafer Card

ZZ-8800 £3.85 + post & packing

Compatible with most reader/programmer units available, this is a multi-chip 'smart card' based on the PIC 16F84A coupled with a 24LC16B EEPROM.

Requires 9-12VDC wall adaptor (Maplin #JC91Y £14.99)

Tiptronic Style Gear Indicator Kit

KC-5344 £20.30 + post & packing

This display indicates up to 9 gears, neutral and reverse. The unit is calibrated in setup, so it will work with almost any vehicle. Using a PIC microcontroller, it calculates the gear via the engine RPM and speed. Gear indication is displayed on a 7 segment LED display, and features an automatic dimmer for night driving. Supplied with case, pre-punched silkscreened front panel, PCB and all electronic components. Hall effect sensor included!
- As published in Everyday Practical Electronics January 2006

AC/DC Current Clamp Meter Kit for DMM's

KC-5368 £8.75 + post & packing

A great low cost alternative. It uses a simple hall effect sensor, an iron ring core and connects to your digital multimeter. It will measure AC and DC current and has a calibration dial to allow for any magnetising of the core. Kit supplied with PCB, clamp, case with silkscreened front panel and all electronic components.
- As published in Everyday Practical Electronics January 2006

Audio Video Booster Kit

KC-5350 £31.95 + post & packing

This kit will boost your video and audio signals preserving them for the highest quality transmission to your projector or large screen TV. It boosts composite, S-Video, and stereo audio signals. Kit includes case with silkscreened and punched panels, PCB and all electronic components.
- As published in Everyday Practical Electronics March 2006

Requires 9VAC wall adaptor (Maplin #GU09K £9.99).

Programmable Continuity Tester Kit

KC-5362 £8.70 + post & packing

This unit will test for continuity from 1-100ohms, making it ideal for measuring low resistance devices. It is accurate, reliable, and works extremely well. Kit supplied with PCB, case with silkscreened panel and all electronic components.
- As published in Everyday Practical Electronics April 2006

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EPE Tutorial Series

TEACH-IN 2006

Part Eight – Digital Electronics: Introducing logic circuits; truth tables; logic families; logic gates.

MIKE TOOLEY BA

Our Teach-In 2006 series provides a broad-based introduction to electronics for the complete newcomer. The series also provides the more experienced reader with an opportunity to "brush up" on topics which may be less familiar. This month we shall be delving into the world of digital electronics – an area that has had an increasing impact on our lives during the last four decades

Digital electronics has brought us the microprocessor and microcomputer as well as a means of exchanging vast amounts of data through local and global networks. But that's not all – digital electronics is used in almost every item of consumer electronic equipment, including CD and DVD players, digital TV and digital audio broadcasting (DAB).

Part Eight of our *Teach-In* series starts by introducing the basic logic functions (AND, OR, NAND, NOR, etc.) together with the symbols and truth tables that describe the operation of the most common logic gates. We then show how these gates can be used in simple combinational logic circuits before moving on to introduce bistable devices, counters and shift registers. Our Practical Investigations this month introduce you to the operation of some simple CMOS logic circuits.

Logic

We all make decisions based on logic in our everyday lives. The sort of decisions that we make are invariably conditional (i.e. they depend on a particular set of circumstances) and they often take the form:

If (condition) then (action).

For example:

If cold then put on the heating

or

If thirsty then go to the bar

We also make compound decisions that are based on more than one set of circumstances and can take the form:

If (condition 1) or (condition 2) then (action).

or

If (condition 1) and (condition 2) then (action).

For example:

If hungry or thirsty then go to the cafe

or

If cold and dark then go to bed

Another possibility is that we might want to make a decision based on the absence of a condition rather than its presence.

For example:

If (condition 1) or (condition 2) and not (condition 3) then (action).

An example of this might be:

If hungry or thirsty and not raining then walk to the pub

The important words in the above conditional statements are "and", "or" and "not". These words describe logical conditions and we will next look at ways in which electronic circuits can emulate the "and" and "or" logic function using circuits that involve nothing more than batteries, switches and lamps.

Logic Circuits

Logic circuits are the basic building blocks of digital circuits and systems and, as their name suggests, they are circuits that are capable of making logical decisions.

Consider the simple circuit shown in Fig.8.1. In this circuit a battery, B1, is connected to a lamp, LP1, via two switches, A and B. It should be obvious that the lamp will only operate when both of the switches are closed (i.e. both A AND B are closed).

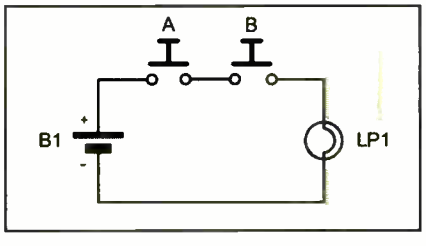

Fig.8.1. AND switch and lamp logic

Switch, A	Switch, B	Lamp, LP1
Open	Open	Off
Open	Closed	Off
Closed	Open	Off
Closed	Closed	On

Fig.8.2. Possible states for the circuit of Fig.8.1

Let's look at the operation of the circuit in a little more detail. Since there are two switches (A and B) and there are two possible states for each switch (open or closed), there is a total of four possible conditions for the circuit. We can summarize these conditions in Fig.8.2.

Note that the two states (i.e. open or closed) are mutually exclusive and that the switches cannot exist in any other state than completely open or completely closed. Because of this, we can represent the state of

A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Fig.8.3. Truth Table for the AND switch and lamp logic

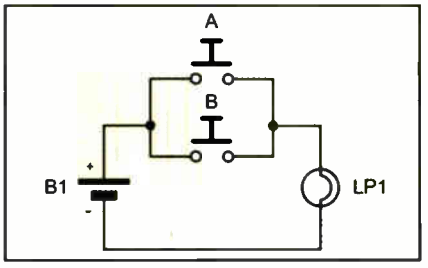

Fig.8.4. OR switch and lamp logic

Switch, A	Switch, B	Lamp, LP1
Open	Open	Off
Open	Closed	On
Closed	Open	On
Closed	Closed	On

Fig.8.5. Possible states for the circuit of Fig.8.4.

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the switches using the binary digits, 0 and 1, where an open switch is represented by 0 and a closed switch by a 1. Furthermore, if we assume that "no light" is represented by a 0 and "light on" is represented by a 1, we can rewrite Fig.8.2 in the form of a Truth Table as shown in Fig.8.3, where Y is the result of the combination of A and B.

Fig.8.4 shows another circuit with two switches. This circuit differs from that shown in Fig.8.1 by virtue of the fact that the two switches are connected in *parallel* rather than in *series*. In this case the lamp will operate when either of the two switches is closed (in other words, when A OR B is closed).

As before, there is a total of four possible conditions for the circuit. We can summarize these conditions in Fig.8.5. Once again, adopting the convention that an open switch can be represented by 0 and a closed switch by 1, we can rewrite the truth table in terms of the binary states as shown in Fig.8.6.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Fig.8.6. Truth Table for the OR switch and lamp logic

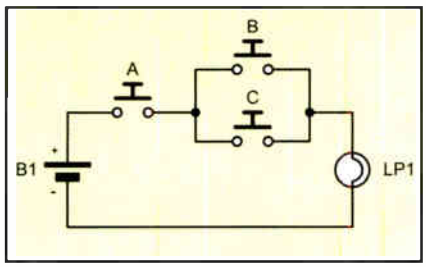


Fig.8.7. Simple switching circuit – see Example 8.1

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Fig.8.8. Truth Table for the simple switching circuit shown in Fig 8.7.

Example 8.1

Fig.8.7 shows a simple switching circuit. Describe the logical state of switches A, B and C in order to operate the lamp.

In order to operate the lamp, switch A AND either switch B OR switch C must be operated. The truth table is shown in Fig.8.8.

Check Point 8.1

Logic circuits involve signals that can only exist in one of two, mutually exclusive, states. These two states are usually denoted by 1 and 0, "on" or "off", "closed" and "open", etc.

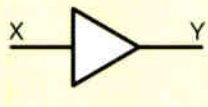
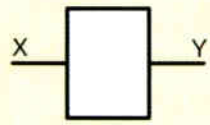
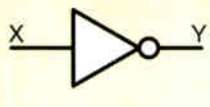
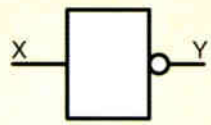
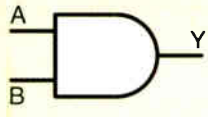
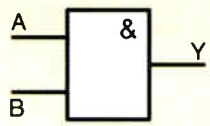
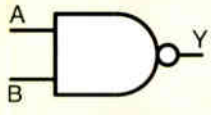
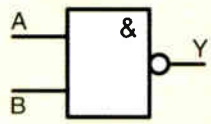
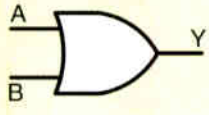
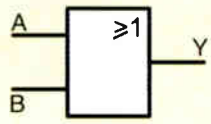
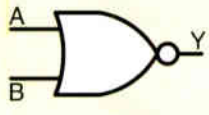
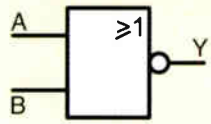
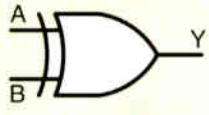
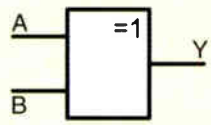
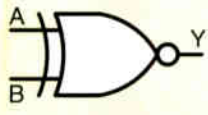
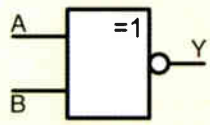
Logic Function	Symbols MIL/ANSI	Symbols BS	Truth Table
Buffer			X Y: 0 0; 1 1
Inverter (NOT)			X Y: 0 1; 1 0
2-input AND			A B Y: 0 0 0; 0 1 0; 1 0 0; 1 1 1
2-input NAND			A B Y: 0 0 1; 0 1 1; 1 0 1; 1 1 0
2-input OR			A B Y: 0 0 0; 0 1 1; 1 0 1; 1 1 1
2-input NOR			A B Y: 0 0 1; 0 1 0; 1 0 0; 1 1 0
2-input Exclusive-OR			A B Y: 0 0 0; 0 1 1; 1 0 1; 1 1 0
2-input Exclusive-NOR			A B Y: 0 0 1; 0 1 0; 1 0 0; 1 1 1

Fig.8.9. Logic gate symbols and truth tables

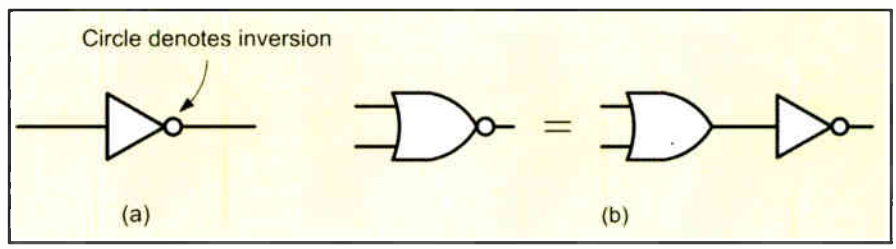


Fig.8.10. Logic gates with inverted outputs

Logic Gates

Logic gates are circuits designed to produce the basic logic functions, AND, OR, NOT, etc. These circuits are designed to be interconnected into larger, more complex, logic circuit arrangements. Each type of logic gate has its own symbol and in Fig.8.9 we have shown both the British Standard (BS) symbol together with the more universally accepted American Standard (MIL/ANSI) symbol. Note that, while inverters and buffers each have only one input, exclusive-OR gates have two inputs and the other basic gates (e.g. AND, OR, NAND and NOR) are commonly available with up to eight inputs.

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Some of the logic gates shown in Fig.8.9 are said to have inverted outputs. These gates are the NOT, NAND, NOR and Exclusive-NOR and the small circle at the output of the gate (see Fig.8.10a) indicates this inversion. It is important to note that the output of an inverted gate (e.g. NOR) is identical to that of the same (i.e. non-inverted) function with its output connected to an inverter (or NOT gate) as shown in Fig.8.10b.

The logical function of a logic gate can also be described using Boolean notation. In this type of notation the OR function is represented by a "+" symbol, the AND function by a "−" sign, and the NOT function by an overscore or "/". Thus the output, Y, of an OR gate with inputs A and B can be represented by the Boolean algebraic expression:

$$Y = A + B$$

Similarly, the output of an AND gate can be shown as:

$$Y = A - B$$

We shall now briefly examine the logical functions of each of the basic logic gates shown in Fig.8.9:

Buffers

Buffers do not affect the logical state of a digital signal (i.e. a logic 1 input results in a logic 1 output whereas a logic 0 input results in a logic 0 output). Buffers are normally used to provide extra current drive at the output but can also be used to regularize the logic levels present at an interface. The Boolean expression for the output, Y, of a buffer with an input, X, is:

$$Y = X$$

Inverters

Inverters are used to *complement* the logical state (i.e. a logic 1 input results in a logic 0 output and vice versa). Inverters also provide extra current drive and, like buffers, are used in interfacing applications where they provide a means of regularizing logic levels present at the input or output of a digital system. The Boolean expression for the output, Y, of an inverter with an input, X, is:

$$Y = /X \text{ (or } Y = \overline{X})$$

AND Gates

AND gates will only produce a logic 1 output when all inputs are simultaneously at logic 1. Any other input combination results in a logic 0 output. The Boolean expression for the output, Y, of an AND gate with inputs, A and B, is:

$$Y = A - B$$

OR Gates

OR gates will produce a logic 1 output whenever any one, or more, inputs are at logic 1. Putting this another way, an OR gate will only produce a logic 0 output whenever *all* of its inputs are simultaneously at logic 0. The Boolean expression for the output, Y, of an OR gate with inputs, A and B, is:

$$Y = A + B$$

NAND Gates

NAND (i.e. NOT-AND) gates will only produce a logic 0 output when all inputs are simultaneously at logic 1. Any other input combination will produce a logic 1 output. A NAND gate, therefore, is nothing more than an AND gate with its output inverted! The circle shown at the output denotes this inversion. The Boolean expression for the output, Y, of a NAND gate with inputs, A and B, is:

$$Y = A - B$$

NOR Gates

NOR (i.e. NOT-OR) gates will only produce a logic 1 output when all inputs are simultaneously at logic 0. Any other input combination will produce a logic 0 output. A NOR gate, therefore, is simply an OR gate with its output inverted. A circle is again used to indicate inversion. The Boolean expression for the output, Y, of a NOR gate with inputs, A and B, is:

$$Y = A + B$$

Exclusive-OR Gates

Exclusive-OR gates will produce a logic 1 output whenever *either* one of the two inputs is at logic 1 and the other is at logic 0. Exclusive-OR gates produce a logic 0 output whenever both inputs have the same logical state (i.e. when both are at logic 0 or both are at logic 1). The Boolean expression for the output, Y, of an exclusive-OR gate with inputs, A and B, is:

$$Y = (\underline{A} - /B) + (\underline{B} - /A) \text{ (or } Y = (A - \overline{B}) + (B - \overline{A}))$$

Exclusive-NOR Gates

Exclusive-NOR gates will produce a logic 0 output whenever *either* one of the two inputs is at logic 1 and the other is at logic 0. Exclusive-NOR gates produce a logic 1 output whenever both inputs have the same logical state (i.e. when both are at logic 0 or both are at logic 1). The Boolean expression for the output, Y, of an exclusive-NOR gate with inputs, A and B, is:

$$Y = (/A - /B) + (\underline{B} - /A) \text{ (or } Y = (\overline{A} - \overline{B}) + (B - \overline{A}))$$

Check Point 8.2

The logical function of a combinational logic circuit (i.e. an arrangement of logic gates) can be described by a truth table or by using Boolean algebra.

Combinational Logic

By using a standard range of logic levels (i.e. voltage levels used to represent the logic 1 and logic 0 states) logic circuits can be combined together in order to solve complex logic functions.

Example 8.2

A logic circuit is to be constructed that will produce a logic 1 output whenever two, or more, of its three inputs are at logic 1.

This circuit could be more aptly referred to as a "majority vote" circuit. Its truth table is shown in Fig.8.11. Fig.8.12 shows the logic circuitry required.

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Fig.8.11. Truth Table for Example 8.2

Example 8.3

Show how an arrangement of AND, OR and NOT gates can be used to produce the exclusive-OR function.

In order to solve this problem, consider the Boolean expression for the exclusive-OR function:

$$Y = (A - /B) + (B - /A)$$

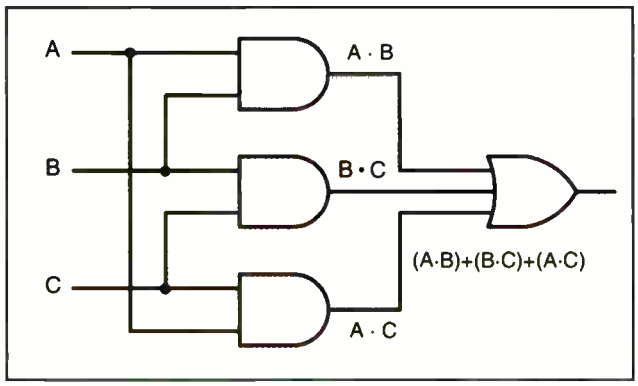

Fig.8.12. Majority vote logic circuit

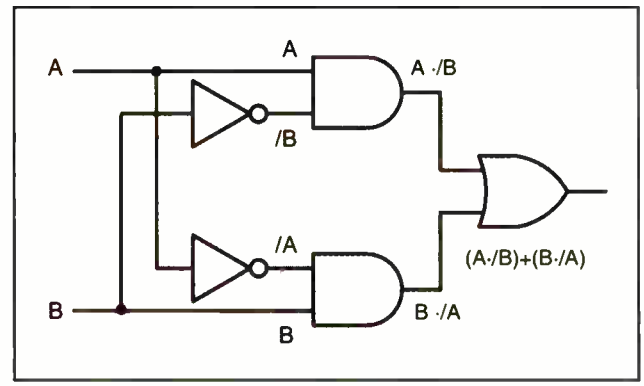

Fig.8.13. An exclusive-OR gate produced from AND, OR and NOT gates

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where /A and /B can be obtained by simply inverting A and B respectively. Then, A − /B and B − /A can be obtained using two two-input AND gates. Finally, these two can be applied to a two-input OR gate in order to obtain the required logic function, (A − /B) + (B − /A). The complete solution is shown in Fig.8.13.

Questions 8.1

Q8.1. Show how three two-input AND gates can be connected together to form a four-input AND gate.

Q8.2. Show how three two-input OR gates can be connected together to form a four-input OR gate.

Q8.3. Draw the truth table for the logic gate arrangement shown in Fig.8.14.

Q8.4. State the Boolean logic expression for the output of each of the gate arrangements shown in Fig.8.15.

Q8.5. Devise a logic gate arrangement that provides an output described by the truth table shown in Fig.8.16.

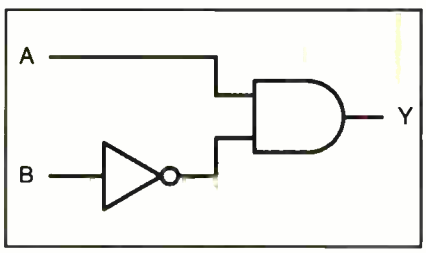

Fig.8.14. See Questions 8.1

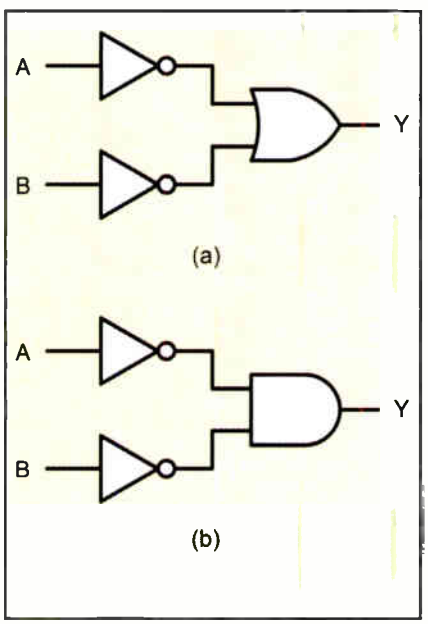

Fig.8.15. See Questions 8.1

Bistables

The output of a bistable circuit has two stables states (logic 0 or logic 1). Once set in one or other of these states, the output of a bistable will remain at a particular logic level

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

Fig.8.16. See Questions 8.1

for an indefinite period until *reset*. A bistable thus forms a simple form of memory as it remains in its latched state (either *set* or *reset*) until a signal is applied to it in order to change its state (or until the supply is disconnected).

The simplest form of bistable is the R-S bistable. This device has two inputs, SET and RESET, and complementary outputs, Q and /Q. A logic 1 applied to the SET input will cause the Q output to become (or remain at) logic 1 while a logic 1 applied to the RESET input will cause the Q output to become (or remain at) logic 0. In either case, the bistable will remain in its SET or RESET state until an input is applied in such a sense as to change the state.

Two simple forms of R-S bistable based on cross-coupled logic gates are shown in Fig.8.17. Fig.8.17a is based on cross-coupled two-input NAND gates while Fig.8.17b is based on cross-coupled two-input NOR gates.

Unfortunately, the simple cross-coupled logic gate bistable has a number of serious shortcomings (consider what would happen if a logic 1 was simultaneously present on both the SET and RESET inputs!) and practical forms of bistable make use of much improved purpose-designed logic circuits such as D-type and J-K bistables.

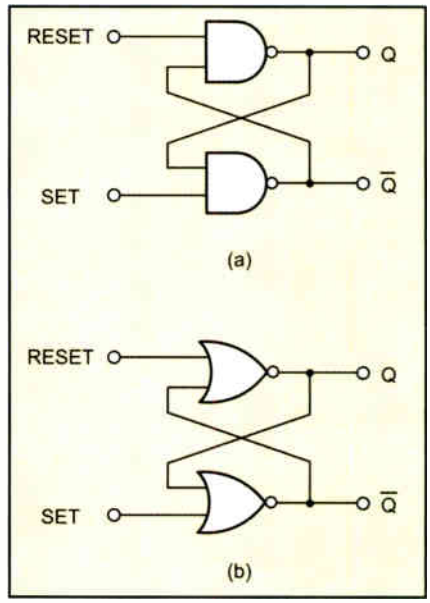

Fig.8.17. Simple R-S bistables (a) based on NAND gates and (b) based on NOR gates

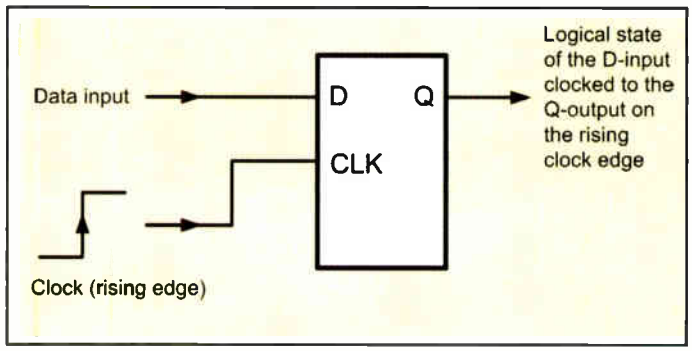

Fig.8.18. The D-type bistable

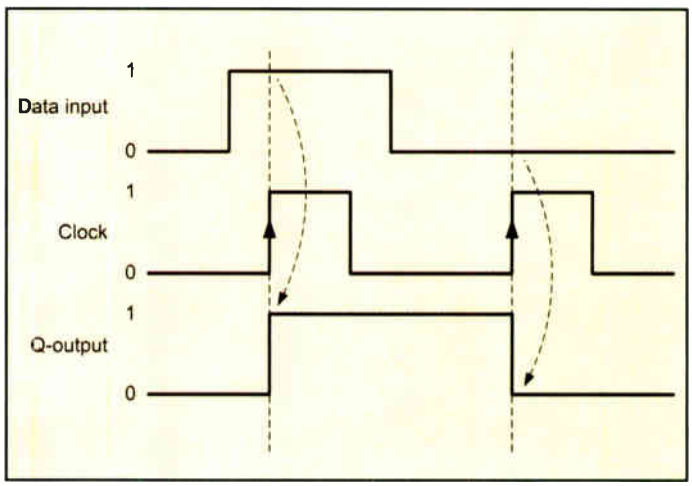

Fig.8.19. Timing diagram for the D-type bistable

The D-type bistable has two inputs: D (standing variously for *data* or *delay*) and CLOCK (CLK). The data input (logic 0 or logic 1) is clocked into the bistable such that the output (Q) state only changes when the clock changes state. Operation is thus said to be *synchronous*. Additional subsidiary inputs (which are invariably active low) are provided which can be used to directly set or reset the bistable.

These are usually called PRESET (PR) and CLEAR (CLR). D-type bistables are used both as latches (a simple form of memory) and as binary dividers. The simple circuit arrangement in Fig.8.18 together with the *timing diagram* shown in Fig.8.19 illustrate the operation of D-type bistables.

J-K bistables (see Fig.8.20) have two clocked inputs (J and K), two direct inputs (PRESET and CLEAR), a CLOCK (CLK) input, and outputs (Q and /Q). As with R-S bistables, the two outputs are complementary (i.e. when one is 0 the other is 1, and vice

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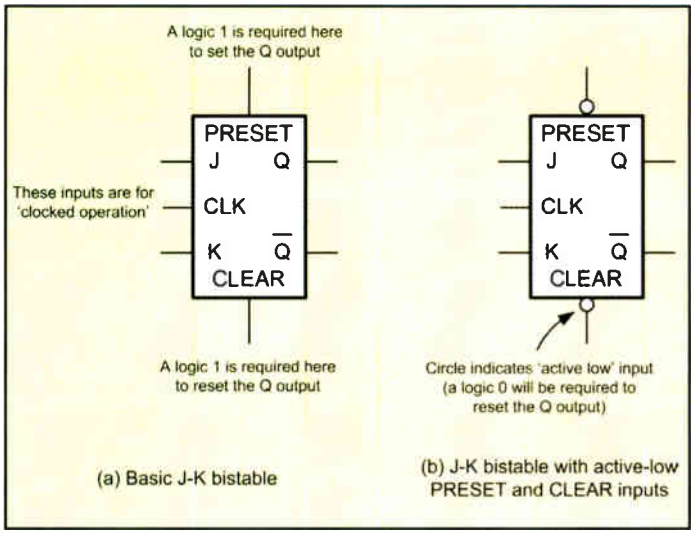

Fig.8.20. J-K bistable

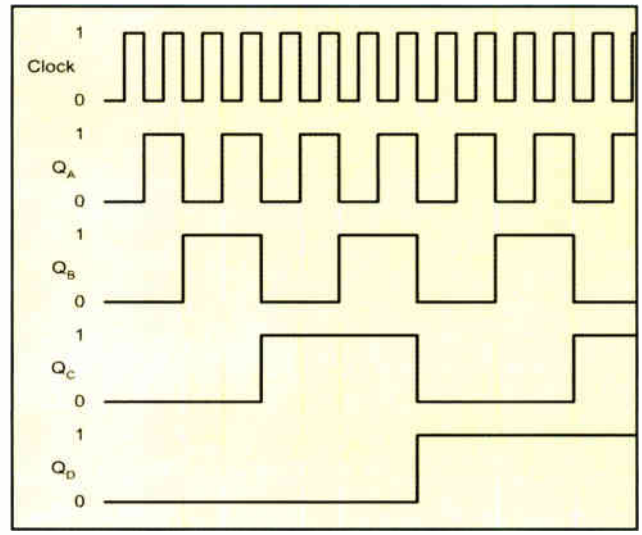

Fig.8.23. Timing diagram for the four-stage binary counter

(a) PRESET and CLEAR inputs

Inputs PRESET	Inputs CLEAR	Output Q	Comment
0	0	?	Indeterminate
0	1	0	Q output changes to 0 (i.e. Q is reset) regardless of the clock
1	0	1	Q output changes to 1 (i.e. Q is reset) on the next clock transition)
1	1	-	Enables clocked operation - refer to the next truth table

Note that the PRESET and CLEAR inputs are unaffected by the state of the clock

(b) Clocked operation using the J and K inputs

Inputs J	Inputs K	Output Q_{N+1}	Comment
0	0	Q_N	No change in state of the Q output on the next clock transition
0	1	0	Q output changes to 0 (i.e. Q is reset) on the next clock transition)
1	0	1	Q output changes to 1 (i.e. Q is reset) on the next clock transition)
1	1	Q_N	Q output changes to the opposite state on the next clock transition

Note that Q_N means 'Q in whatevwer state it was before' whilst Q_{N+1} means 'Q after the next clock transition'

Fig.8.21. J-K bistable operation

versa). Similarly, the PRESET and CLEAR inputs are invariably both active low (i.e. a 0 on the PRESET input will set the Q output to 1 whereas a 0 on the CLEAR input will set the Q output to 0). Fig.8.21 summarizes the input and corresponding output states of a J-K bistable for various input states. J-K bistables are the most sophisticated and flexible of the bistable types and they can be configured in various ways, including binary dividers, shift registers, and latches.

Fig.8.22 shows the arrangement of a four-stage binary counter based on J-K bistables. The timing diagram for this circuit is shown in Fig.8.23. Each stage successively divides the clock input signal by a factor of two. Note that a logic 1 input is transferred to the respective Q-output on the *falling* edge of the clock pulse and all J and K inputs must be taken to logic 1 to enable binary counting.

Fig.8.24 shows the arrangement of a four-stage shift register based on J-K bistables. The timing diagram for this circuit is shown in Fig.8.25. Note that each stage successively feeds data (Q output) to the next stage. Note that all data transfer occurs on the falling edge of the clock pulse.

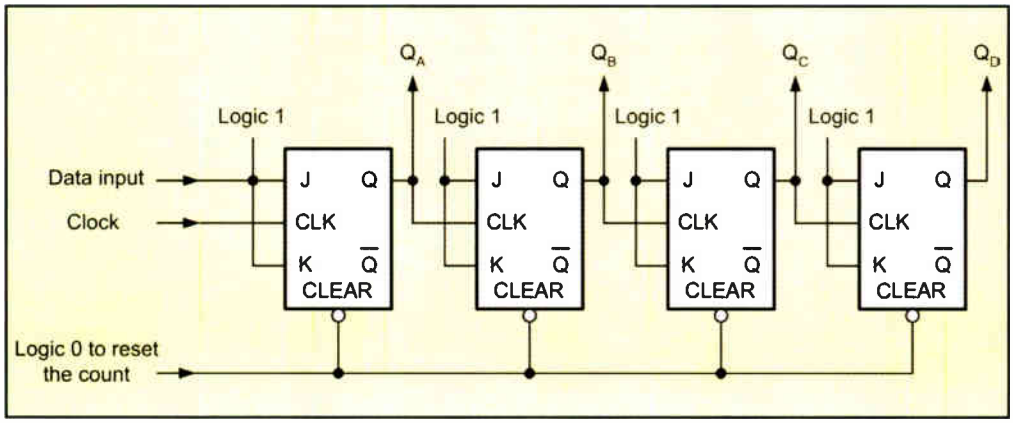

Fig.8.22. Four-stage binary counter using J-K bistables

Check Point 8.3

Bistable devices provide us with a way of storing a transient logical state. More advanced bistable devices (such as J-K bistables) can be configured for use in a variety of different ways, including operation as counters and shift registers.

Logic Families

The task of realizing a complex logic circuit is made simple with the aid of digital integrated circuits which are classified according to the semiconductor technology used in their fabrication (the logic family to which a device belongs is largely instrumental in determining its operational characteristics, such as power consumption, speed, and immunity to noise).

The two basic logic families are *complementary metal oxide semiconductor* (CMOS) and *transistor-transistor logic* (TTL). Each of these families is then further subdivided into classes that are based on refinements of the technology,

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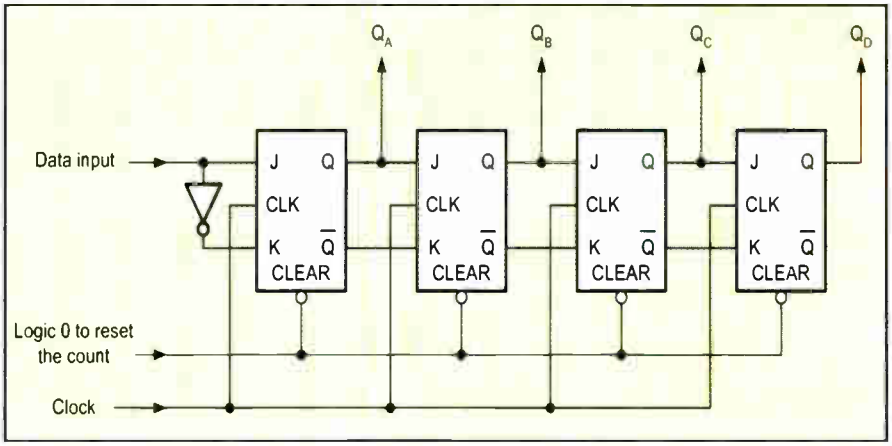

Fig.8.24. Four-stage shift register using J-K bistables

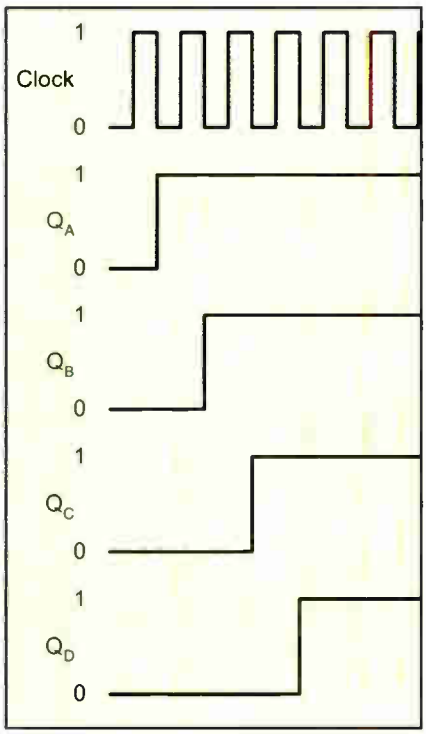

Fig.8.25. Timing diagram for the four-stage shift register

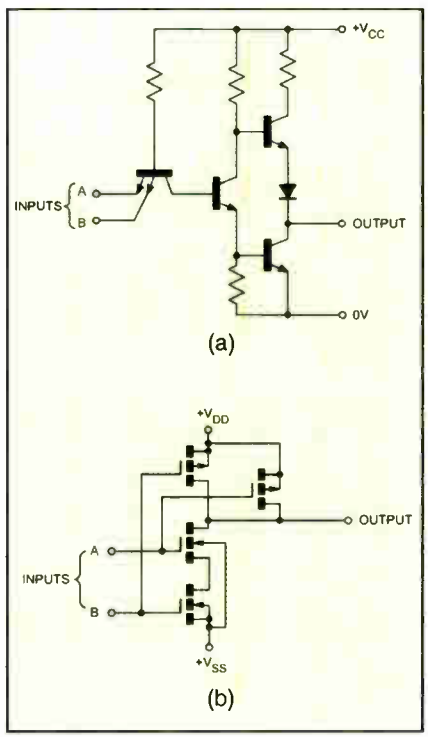

Fig.8.26. Representative internal circuitry for a two-input logic gate in (a) standard TTL and (b) standard CMOS technology

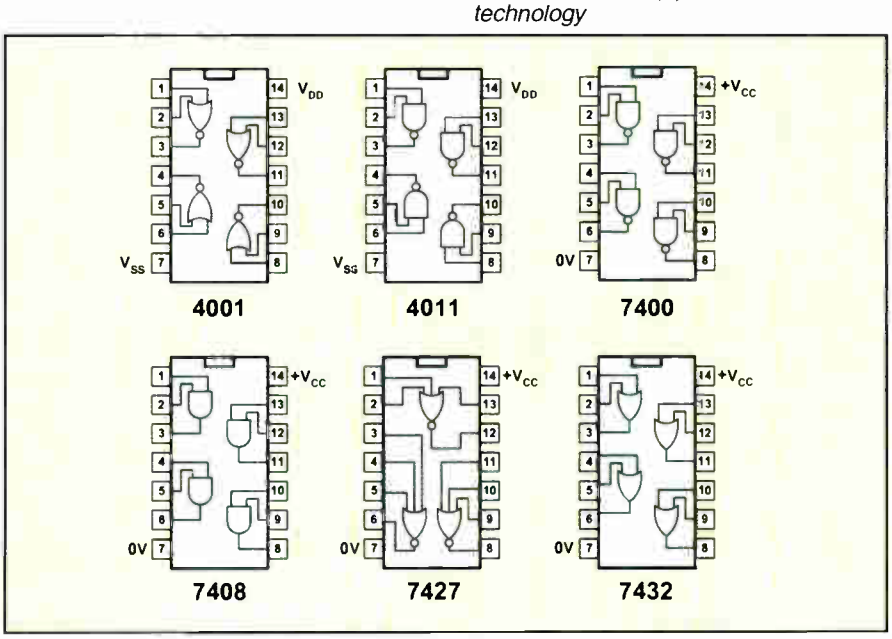

Fig.8.27. Pin connections for the DIL packaged versions of some common CMOS and TTL devices

such as "high-current" (or *buffered* output), low-noise, etc. Representative circuits for a basic two-input NAND gate using TTL and CMOS technology are shown in Fig.8.26a and Fig.8.26b, respectively.

The most common family of TTL logic devices is known as the 74-series. Devices from this family are coded with the prefix number 74, for example, 7400. Variants within the family are then distinguished by letters which follow the initial prefix, for example:

74F00 a device that uses fast TTL technology and operates at higher speed than the 7400 with which it is logic and pin-compatible

74LS08 a device that is logic and pin-compatible with the 7408 but which uses *low-power Schottky* technology

74HCT74 a high-speed CMOS version of the 7474 which has CMOS-compatible inputs

74ALS32 a device that is logic and pin-compatible with the 7432 but which uses *advanced low-power Schottky* technology

The most common family of CMOS devices is known as the 4000-series. Variants within the family are identified by the suffix letters, for example:

4001UB a standard (un-buffered) CMOS devices that is logic and pin-compatible with the 4001B

4011B a device that is logic and pin-compatible with the 4001UB but which has buffered outputs

4069UB a device that is logic and pin-compatible with the 4069B but which has unbuffered outputs

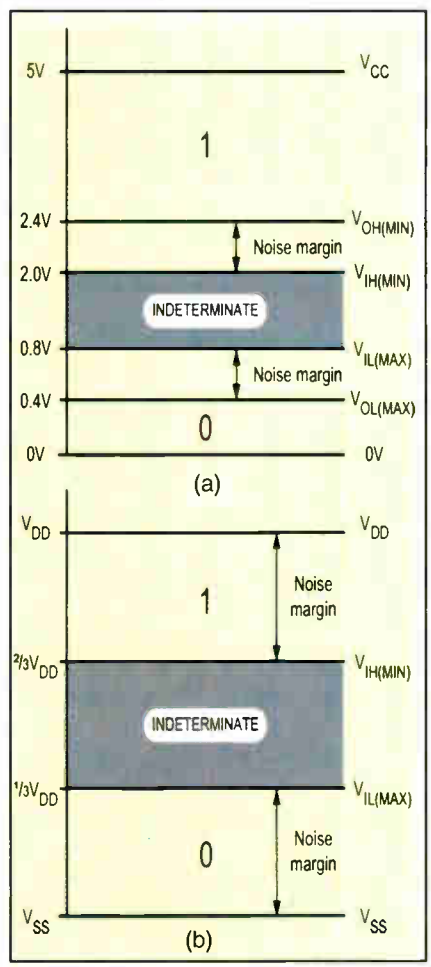

Fig.8.28. Logic levels for (a) standard TTL and (b) standard CMOS logic devices

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It is important to note that manufacturers often add their own prefix and suffix letters to a basic device code. Some typical TTL and CMOS devices supplied in standard dual-in-line (DIL) packages are shown in Fig.8.27. Note that these devices are also available in different package styles, such as leadless flat packages designed for surface mounting.

Finally, it is also worth noting that the vast majority of logic devices and other digital integrated circuits are marked with a four digit date code. The code often appears alongside or below the device code. The first two digits of this code give the year of manufacture while the last two digits specify the week of manufacture.

Logic Levels

Logic levels are simply the range of voltages used to represent the logic states 0 and 1. The logic levels for CMOS differ markedly from those associated with TTL. In particular, CMOS logic levels are relative to the supply voltage used while the logic levels associated with TTL devices tend to be absolute (see Fig.8.28).

The noise margin of a logic device is a measure of its ability to reject noise and spurious signals; the larger the noise margin the better is its ability to perform in an environment in which noise is present. Noise margin is defined as the difference between the minimum values of high state output and high state input voltage and the maximum values of low state output and low state input voltage. Hence:

noise margin = $V_{OH(MIN)} - V_{IH(MIN)}$

or

noise margin = $V_{OL(MAX)} - V_{IL(MAX)}$

where $V_{OH(MIN)}$ is the minimum value of high state (logic 1) output voltage, $V_{IH(MIN)}$ is the minimum value of high state (logic 1) input voltage, $V_{OL(MAX)}$ is the maximum value of low state (logic 0) output voltage, and $V_{IL(MAX)}$ is the minimum value of low state (logic 0) input voltage.

The noise margin for standard 7400 series TTL is typically 400mV while that for CMOS is $1/3V_{DD}$, as shown in Fig.8.28.

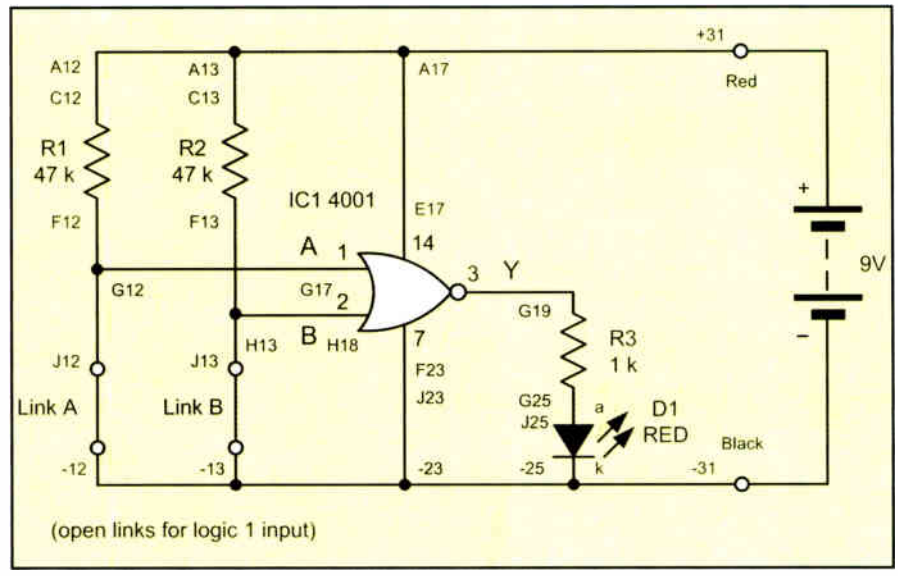

Fig.8.29. Circuit diagram for Practical Investigation 8.1

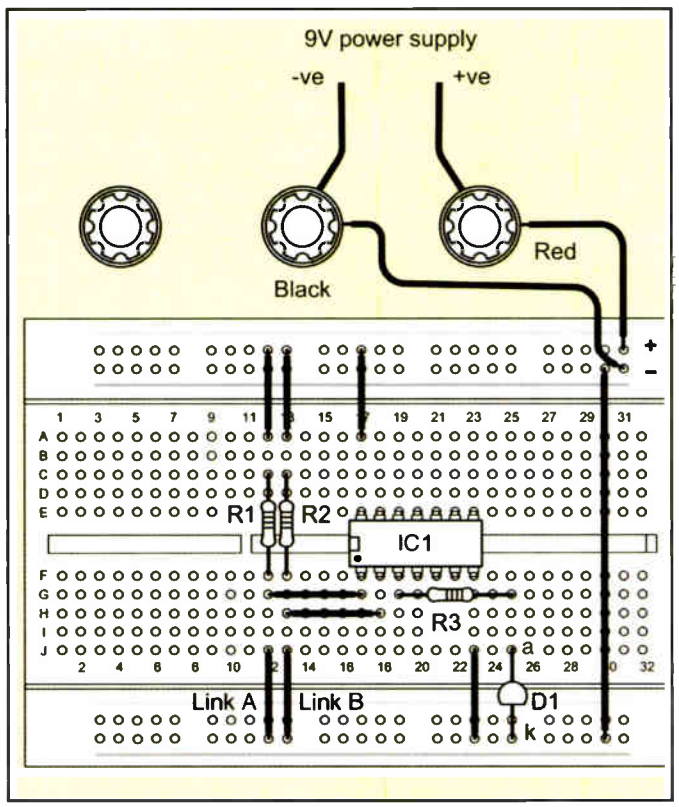

Fig.8.30. Wiring diagram for Practical Investigation 8.1

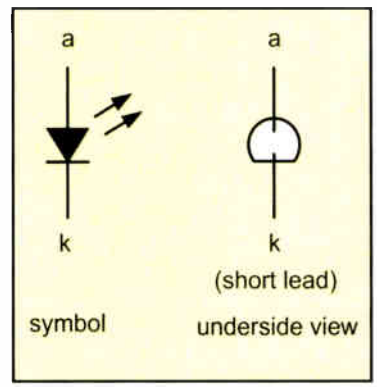

Fig.8.31. Connections for the LED

(b) Truth table:

A	B	Y
0	0	
0	1	
1	0	
1	1	

(a) Table of results:

Link A	Link B	LED D1
present	present	
present	removed	
removed	present	
removed	removed	

Link present = 0 LED non-illuminated = 0

Link removed = 1 LED illuminated = 1

Fig.8.32. Table of results for the two-input NOR gate investigation

Practical Investigation 8.1

Objective: To investigate the operation and obtain the truth table for (a) a two-input CMOS NOR gate and (b) a two-input CMOS NAND gate.

Check Point 8.4

The two main logic families are CMOS and TTL. These two families have quite different characteristics, supply requirements, and logic levels. CMOS logic devices operate from a wide range of voltage levels and consume very little power (and are therefore often preferred for portable low-power applications). TTL logic devices, on the other hand, tend to be faster but have a much lower noise margin and are therefore more susceptible to noise and interference.

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Table 8.1. Breadboard wiring for Practical Investigation 8.1

Step	Connection, link or component	From	To
1	9V supply (negative)	Supply negative	Black terminal
2	9V supply (+9V)	Supply positive	Red terminal
3	Red wire	Red terminal	+31
4	Black wire	Black terminal	–31
5	Link	–30 (top)	–30 (bottom)
6	Link	J23	–23 (bottom)
7	Link (Link A)	J12	–12 (bottom)
8	Link (Link B)	J13	–13 (bottom)
9	Link	+12	A12
10	Link	+13	A13
11	Link	+17	A17
12	Link	G12	G17
13	Link	H13	H18
14	IC1 4001	Pin 1	F17
15	IC1 (as above)	Pin 7	F23
16	IC1 (as above)	Pin 8	E23
17	IC1 (as above)	Pin 14	E17
18	R1 47kΩ	C12	F12
19	R2 47kΩ	C13	F13
20	R3 1kΩ	G19	G25
21	D1 LED	anode	J25
22	D1 (as above)	cathode	–25 (bottom)

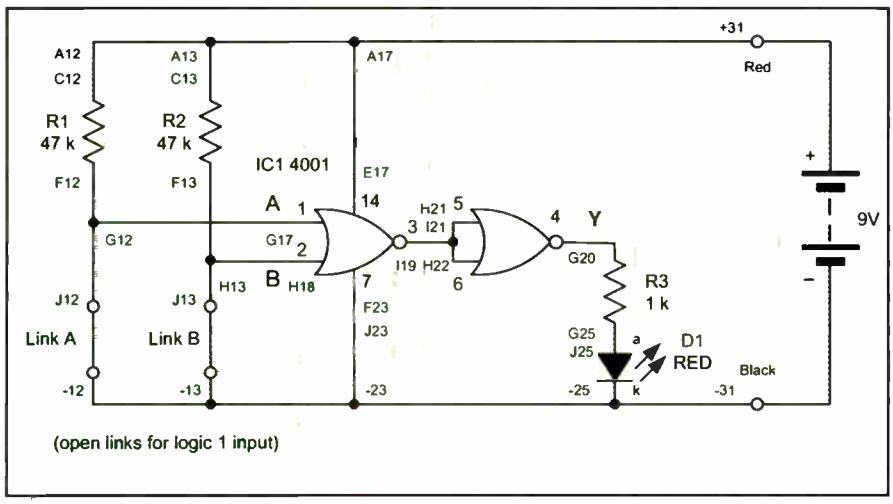

Fig.8.33. Circuit diagram for Practical Investigation 8.2

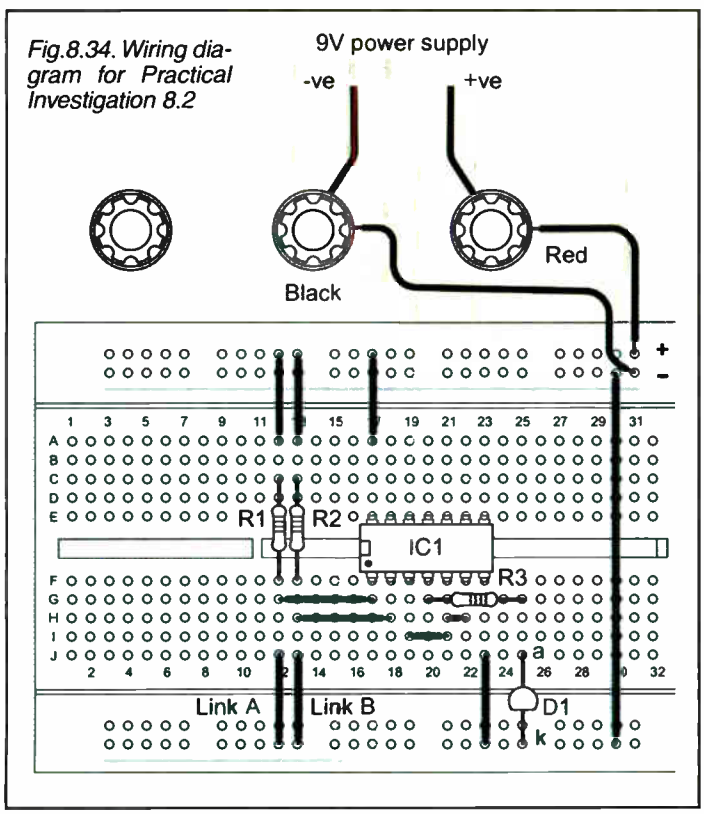

Fig.8.34. Wiring diagram for Practical Investigation 8.2

Components and materials: Plug-in breadboard; 9V DC power source (PP9 9V battery or AC mains adapter with a 9V 400mA output); 4001 and 4011 14-pin DIL CMOS logic integrated circuits; red LED; resistors of 47kΩ (2 required) and 1kΩ; insulated wire links (various lengths); short lengths of black and red insulated solid wire.

Circuit diagram: See Fig.8.29
Wiring diagram: See Fig.8.30 and Fig.8.31

Procedure: The required breadboard wiring is shown in Table 8.1.

1. Connect the circuit as shown in Table 8.1 with the 4001 CMOS (quad two-input NOR gate) used for IC1.
2. Ensure that both Link A and Link B are connected (this corresponds to an input state of A = 0 and B = 0).
3. Switch on (or connect the 9V supply) and observe the state of the LED. Note down whether the LED is illuminated or not illuminated using the table of results shown in Fig.8.32.
4. Disconnect first link B (with link A in place) and then link A (with link B in place). In the first condition B = 1 and A = 0 and in the second condition B = 0 and A = 1. For each of these two conditions, observe the state of the LED and add your results to Fig.8.32.
5. Finally, disconnected both links (so that A = 1 and B = 1) and add the final line to your results.
6. Switch off (or disconnect the 9V supply), replace IC1 with a 4011 CMOS (quad two-input NAND gate and repeat steps 1 to 6 above, recording your results in a separate table.

Conclusion: Verify that both devices produce the expected logical functions and truth tables.

Practical Investigation 8.2

Objective: To investigate the operation and obtain the truth table for (a) a two-input OR gate and (b) a two-input AND gate.
Components and materials: As for Practical Investigation 8.2.
Circuit diagram: See Fig.8.33
Wiring diagram: See Fig.8.34

Procedure: The required breadboard wiring is the same as that for Practical Investigation 8.1 in Table 8.1, with the changes shown in Table 8.2.

Table 8.2. Breadboard wiring for Practical Investigation 8.2

Step	Connection, link or component	From	To
20	R3 1kΩ	G20	G25
23	Link	I19	I21
24	Link	H21	H22

The rest of the procedure is the same as that used for steps 1 to 6 of the procedure for Practical Investigation 8.1. Once again, you should show your results in a truth table similar to that shown in Fig.8.32.

Conclusion: Verify that logic arrangements produce the expected logical functions and truth tables.

Part 9

In Part 9, next month, we shall give the answers to this month's questions and introduce microprocessors. In the meantime you might like to see how you get on with our online quiz for Part 8. You will find this at **www.miketooley.info/tech-in/quiz8.htm**

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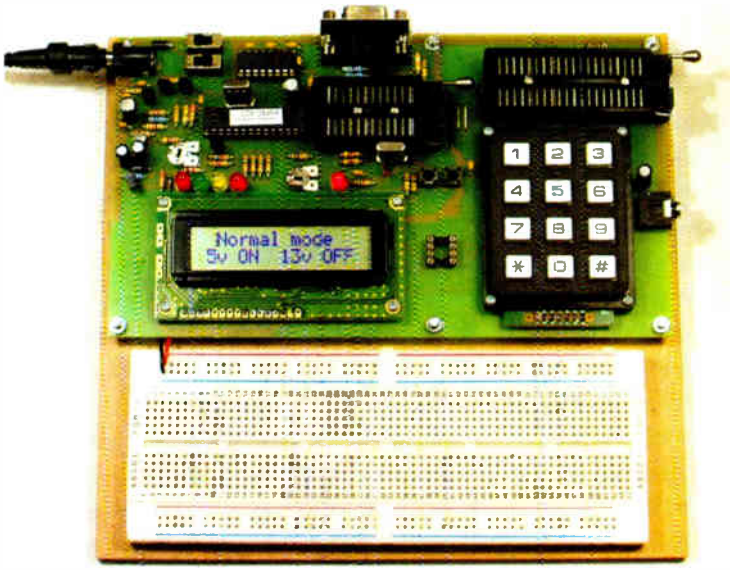
Learn About Microcontrollers



PIC Training & Development System

The best place to start learning about microcontrollers is the PIC16F84 with its simple easy to understand internal structure. Then continue on using the more sophisticated PIC16F877 family.

At the heart of our system are two real books which lie open on your desk while you use your computer to type in the programme and control the hardware. Start with four simple programmes. Run the simulator to see how they work. Test them with real hardware. Follow on with a little theory.....

Our PIC training course consists of our mid range PIC programmer, a 298 page book teaching the fundamentals of PIC programming in assembly language, a 274 page book introducing the C programming language for PICs, and a suite of programmes to run on a PC. The module is an advanced design using a 28 pin PIC16F870 to handle the timing, programming and voltage switching requirements. Two ZIF sockets and an 8 pin socket allow most mid range 8, 18, 28 and 40 pin PICs to be programmed. The plugboard is wired with a 5 volt supply. The programming is performed at 5 volts, verified with 2 volts or 3 volts applied and verified again with 5.5 volts applied to ensure that the PIC is programmed correctly over its full operating voltage. UK orders include a plugtop power supply.

Universal mid range PIC programmer module
+ Book Experimenting with PIC Microcontrollers
+ Book Experimenting with PIC C
+ PIC assembler and C compiler software suite
+ PIC16F84 and PIC16F870 test PICs. £159.00
(Postage & insurance UK £10, Europe £15, Rest of world £25)

Which Language to Learn

Everyone should start programming PICs using assembly language. That is the only way to fully understand what happens. Then there are good arguments in some applications to change over to using a high level language, but, BASIC or C? At the beginning BASIC is easy to learn while C can seem very strange, but the weakness of BASIC comes from its ease of use, while the power of C lurks in its strangeness. Once the early stages are past programmes are easier to write in C than in BASIC.

Experimenting with PIC Microcontrollers

This book introduces PIC assembly language programming using the PIC16F84, and is the best way to get started for anyone who is new to PIC programming. We begin with four easy experiments, the first of which is explained over ten and a half pages assuming no starting knowledge of PICs. Then having gained some practical experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Fur Elise*. Finally there are two projects to work through, using the PIC16F84 as a sinewave generator and investigating using the PIC16F88 (from the PIC16F877 family) to monitor the power taken by domestic appliances. In the space of 24 experiments, two projects and 56 exercises the book works through from absolute beginner to experienced engineer level.

Web site:- www.brunningsoftware.co.uk

PIC C Language

The second book *Experimenting with PIC C* starts with an easy to understand explanation of how to write simple PIC programmes in C. The first few programmes are written for a PIC16F84 to keep continuity with the first book *Experimenting with PIC Microcontrollers*. Then we see how to use the same C programmes with the PIC16F627 and the PIC16F877 family.

We study how to create programme loops using C, we experiment with the IF statement, use the 8 bit and 16 bit timers, write text, integer and floating point variables to the liquid crystal display, and use the keypad to enter numbers.

Then its time for 25 pages of pure study, which takes us much deeper into C than is directly useful with PICs as we know them - we are studying for the future as well as the present. We are not expected to understand everything that is presented in these 25 pages, the idea is to begin the learning curve for a deep understanding of C.

In chapter 9 we use C to programme the PIC to produce a siren sound and in the following chapter we create the circuit and software for a freezer thaw warning device. Through the last four chapters we experiment with using the PIC to measure temperature, create a torch light with white LEDs, control the speed of one then two motors, study how to use a PIC to switch mains voltages, and finally experiment with serial communication using the PIC's USART.

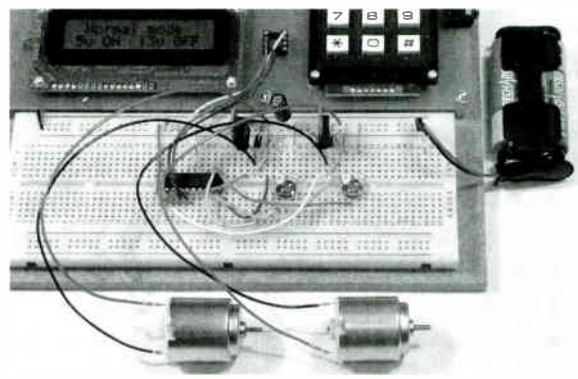
Some of the programmes towards the end of *Experimenting with PIC C* are shown in assembler and C to enable the process to be fully explained, and in the torch light experiments, due to the fast switching speed, the programmes are written only in assembler.

As you work through this book you will be pleasantly surprised how C makes light work of calculations and how easy it is to display the answers.

Ordering Information

The programmer module connects to the serial port of your PC (COM1 or COM2). All our software referred to in this advertisement will operate within Windows 98, XP, NT, 2000 etc.

Telephone with Visa, Mastercard or Switch, or send cheque/PO. All prices include VAT if applicable.



White LED and Motors

Our PIC training system uses a very practical approach. Towards the end of the second book circuits need to be built on the plugboard. The 5 volt supply which is already wired to the plugboard has a current limit setting which ensures that even the most severe wiring errors will not be a fire hazard and are very unlikely to damage PICs or other ICs.

We use a PIC16F627 as a freezer thaw monitor, as a step up switching regulator to drive 3 ultra bright white LEDs, and to control the speed of a DC motor with maximum torque still available. A kit of parts can be purchased (£30) to build the circuits using the white LEDs and the two motors. See our web site for details.

Mail order address:

Brunning Software **138 The Street, Little Clacton, Clacton-on-sea, Essex, CO16 9LS. Tel 01255 862308**

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Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been published or submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown, Dorset BH22 9ND. (We **do not** accept submissions for IU via email). Your ideas could earn you some cash **and a prize!**

Super Vibration Switch – *A Gentle Turn-on*

THE circuit in Fig.1 represents a substantial increase in sensitivity compared to other designs. It is designed as a drop-in replacement for the traditional vibration switch. An indicator light D1 indicates that vibration has been detected, and it has three terminals, +12V, 0V, and OUT. OUT goes logic "high" when vibration is detected.

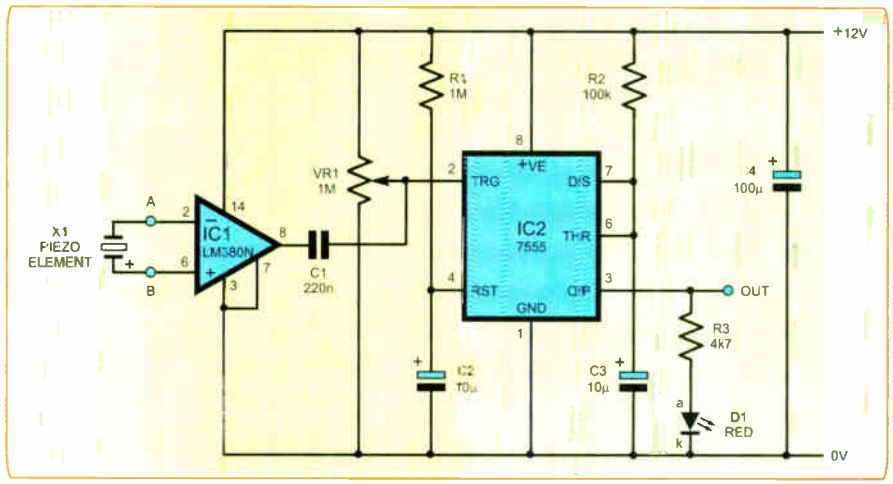

Fig.1. Complete circuit diagram for the Super Vibration Switch

Circuit Details

The Super Vibration Switch uses a cheap, standard piezo element which flexes slightly in response to vibrations, thus creating a minute electrical output. At the heart of its "front end" (see Fig.1) is the veteran LM380N. This IC is chosen for its lightly biased inputs, its automatically centred output, and its internal positive feedback, which enormously amplifies the electrical output of piezo element X1. Not only this, but X1 is isolated from the rest of the circuit, so that supply decoupling is not a critical issue.

Potentiometer VR1 biases the trigger input of monostable IC2. Since a single component (VR1) is used here, there is no danger of drift from mismatched temperature coefficients. Capacitor C1 serves for DC blocking.

IC2 is wired as a standard monostable timer. With the values of R2 and C3 as shown, this delivers a positive-going output pulse of about one second, illuminating LED D1. The author chose an ultrabright LED for D1, since this was easier to see at a distance. IC2 includes a timed delay of a few seconds at reset pin 4 (R1 and C2), to prevent any spurious triggering at switch-on.

Sensor Elements

To mount the sensor (see Fig.2), the author drilled a 3mm hole at one edge of the piezo element, near the base of its wires, and soldered a washer to the hole. He inserted a 20mm long, 3mm diameter bolt through the washer, and secured the piezo element as shown. This assembly was then fixed to the PCB, with the bolt serving as the negative terminal. The "suspended" end of the piezo element ideally needs to be weighted, in such a way that most of the element will be free to flex.

The greater the weight, the better, since that increases inertia. However, since this is a flimsy(ish) piezo element, it has a natural limit. One could say a few grams.

The Super Vibration Switch draws about 13mA on standby. Therefore for long-term use it should use a regulated power supply. Attach a 12V battery or regulated power supply, and wait a few seconds for IC2 to reset.

If LED D1 illuminates all the time, then VR1 needs to be adjusted towards +12V. If

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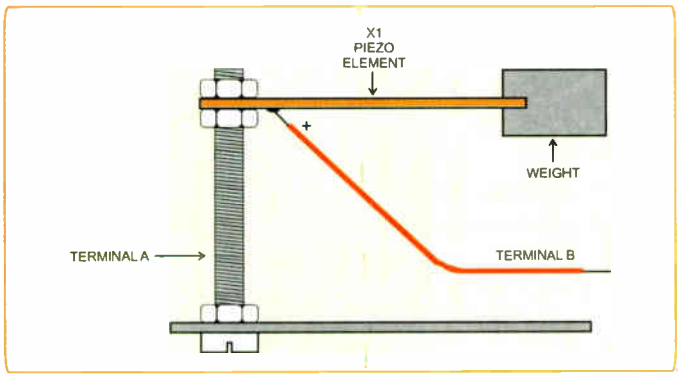

Fig.2. Mechanical setup for the vibration element

D1 does not illuminate at all, then VR1 needs to be adjusted towards 0V. The Super Vibration Switch is best placed on a surface which is most directly affected by the vibration you want to pick up.

If an ordinary encased piezo sounder is used in place of X1, the circuit may serve as a sensitive clap switch. Alternatively, a neodymium magnet may be used to weight the piezo element, in which case this would convert the circuit into a magnetic switch, responding to a moving magnet with a range of up to about 100mm.

Without any special effort, the switch may be adjusted very sensitively indeed. The author's prototype was capable of picking up a pin striking a wooden floor at a few metres' distance, and easily picked up the vibration of cars passing in the street.

Thomas Scarborough
Cape Town, South Africa.

Simple Sonar – *Disco Tech*

AS IF there were no end to what may be done with the LM380N amplifier IC, the circuit in Fig.3 shows a Simple Sonar employing just four components. The circuit description is equally simple.

Piezo sounder X1 serves as a microphone, while piezo X2 serves as a sounder. When X1 and X2 are brought into close proximity, a feedback loop is created, so that X2 sounds loudly at its resonant frequency. Ideally X1 and X2 will be identical; they are the usual cheap brass discs enclosed in plastic (without integral electronic driver circuits).

Resistor R1 is necessary to limit output current. Its value may be reduced to as little as a few tens of ohms if desired, to increase sensitivity by about a third. Without R1, the circuit would work initially, but IC1 would soon go into thermal shutdown.

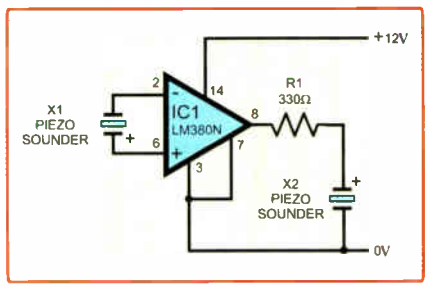

Fig.3. Full circuit diagram for the Simple Sonar

X1 and X2 may be mounted a few centimetres apart – just far enough not to create feedback. When an object (e.g. a car bumper) comes within about 10cm of X1 and X2, piezo sounder X2 screeches at its resonant frequency. Since the LM380N's current consumption is not the most modest (about 12mA in this application), this circuit would ideally be run off a 12V DC plugpack power supply.

Thomas Scarborough
Cape Town, South Africa

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EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

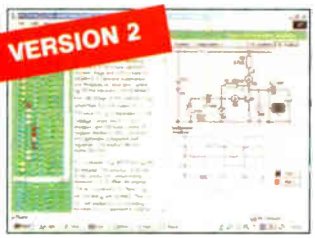
ELECTRONICS PROJECTS

Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

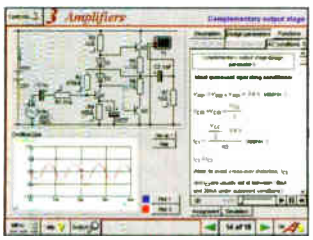
VERSION 2



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols.
Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

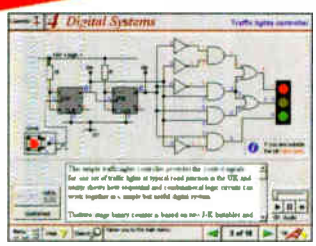


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

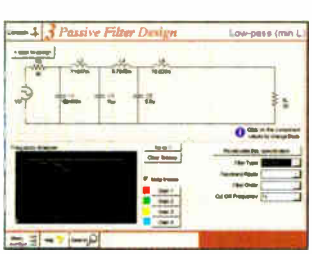
VERSION 2



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

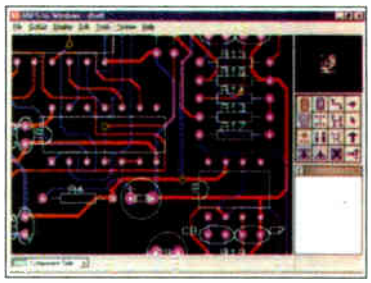
ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS

Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	**£45 inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99 *plus* VAT**
Institutional 10 user (Network Licence)	**£249 *plus* VAT**
Site Licence	**£499 *plus* VAT**

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

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PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

VERSION 3 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Can be powered by USB (no power supply required)

£158 including VAT and postage

supplied with USB cable and programming software

SOFTWARE

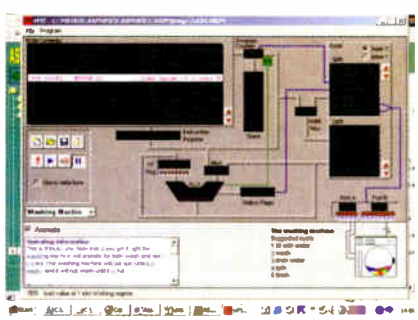
Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

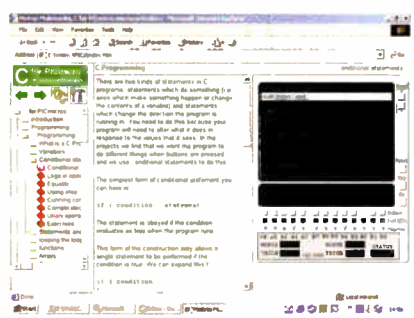


'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

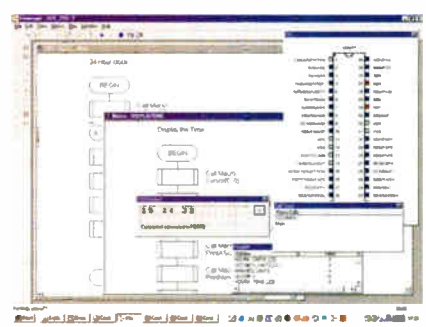
FLOWCODE FOR PICmicro V2

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 18, 28 and 40-pin devices ● Professional versions include virtual systems (burglar alarm, buggy and maze, plus RS232, IrDa etc.).



PRICES

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(Order form on next page)

Hobbyist/Student	£45 inc VAT
Flowcode V2 Hobbyist/Student	£57 inc VAT
Institutional (Schools/HE/FE/Industry)	£99 *plus* VAT
Flowcode Professional	£99 *plus* VAT
Institutional/Professional 10 user (Network Licence)	£300 *plus* VAT
Site Licence	£599 *plus* VAT

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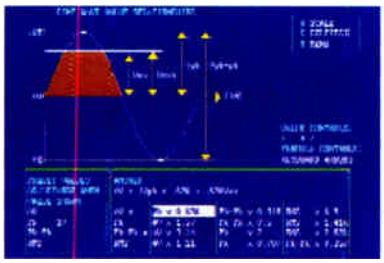

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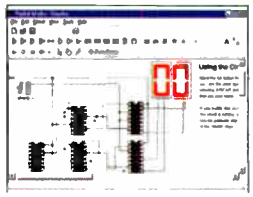

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UK, US and European ring tones plus a basic test

By TERRY DE VAUX-BALBIRNIE

THIS circuit will ring a telephone in the UK, US or European style and also perform a basic check on the speech circuit. Of course, some people will wish to construct it for only one of these purposes.

One application would be to ring a phone for a stage production. The effect would be convincing to the audience (not usually the case when a person offstage using a bell push, battery and buzzer tries to imitate the UK style ring!).

The circuit will operate either a modern electronic phone or a traditional one having a mechanical sounder. It could therefore be useful for period productions. Note, however, that any traditional phone would need to be fitted with a modern BT type plug and converted as necessary.

Tape recorded telephone rings are sometimes used for plays but these are never altogether satisfactory. One reason is that it is usually obvious to the audience that the sound is not coming from the phone. A further point is that the operator off-stage needs to stop the tape machine as soon as the person lifts the receiver and this requires some care. With this device, the ringing stops as the handset is lifted.

Being self-contained and battery operated, the unit may be taken to a car boot sale to check phones offered for sale. Bargains are to be had but there is also a lot of rubbish on offer.

Appearance

The circuit is built in a plastic box (see photograph). On the side, there are four switches labelled ON, RING/SHOW, TEST and UK/US/EUR. The latter is a rotary unit which selects the ring style. There is also a neon indicator and a control which varies the ring signal frequency. This is not normally

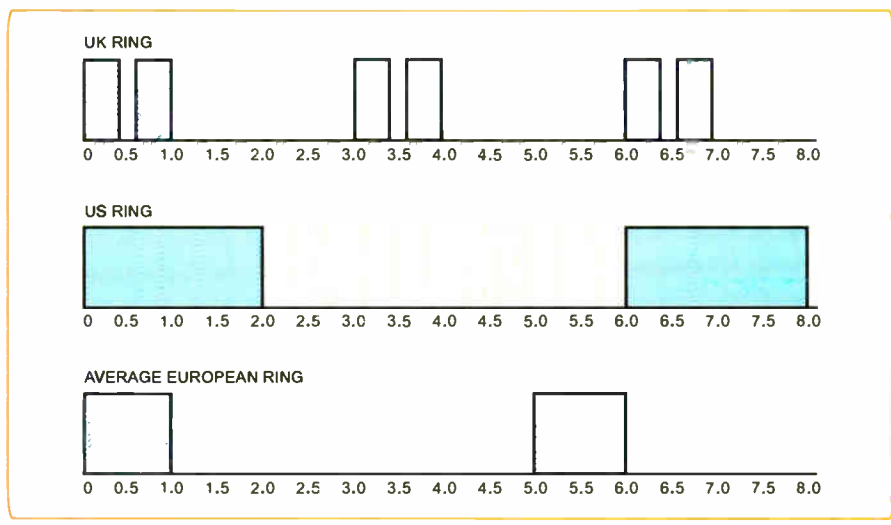

Fig.1: Cadence of UK, USA and average European ring styles

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used for modern telephones but may need to be adjusted when using old units having a mechanical bell system. On top of the box there is a UK-style telephone socket.

The RING/SHOW switch may be used to start the ringing cycle at the right time. This is useful for stage performances. For example, for the UK tone, it is best for the phone to "switch on" just before the double ring. With the switch set to SHOW, the neon indicator will flash in sympathy with the ring signal. The user then switches to RING at the chosen moment. The TEST pushbutton switch allows the user to listen to his or her own voice through the earpiece. More will be said about this later.

Dead Ringer

A double ring cadence (ring-ring .... ring-ring) is used in the UK, Australia, the Irish Republic and several other countries. This generally follows the pattern 0·4s on, 0·2s off, 0·4s on, 2s off then repeat. One cycle therefore occupies three seconds. Other countries usually use some form of single ring (although a continuous tone is occasionally found).

The North American model follows the pattern two seconds on, four seconds off then repeat – the cycle taking six seconds. In continental Europe, the ring tone is generally on for one second and off for three or four seconds. In France, it is on for 1·5 seconds and off for 3·5 seconds. Due to the wide variation in detail of European ring tones, this circuit is set to give an average effect of one second on and four seconds off as used, for example, in Germany, Italy and the Netherlands. Fig.1 shows the UK, US and "average European" cadence.

It is said that television viewers in the United States are familiar with the UK-style double ring tone because it is often heard in programmes broadcast there. This leads many people to think that it is the pattern used throughout Europe. Nothing could be further from the truth!

However, knowing that this misconception exists, the UK ring tone is often used by American producers for a programme set in any European country and this perpetuates the myth. On the other hand, those living in the UK are familiar with the single ring pattern heard when on holiday in the USA or on the continent, but many do not know that variations exist between the various countries.

Facts and Figures

Whatever the pattern, the ringing signal comprises bursts of alternating current (in Europe the frequency is usually 25Hz while in the US it is 20Hz). The signal is then sent along the telephone line at some 70 volts. The value varies from country to country (it may be as high as 150V) and falls with increasing load (the number of telephones connected to the line). Using a high-voltage system reduces the voltage drop across the resistance of a long telephone line.

The operating frequency is not critical when using an electronic phone. However, old units having a mechanical ringer need a

Parts List – Phone Ring & Test

1 PC board coded 574, available from the *EPE PCB Service*
1 plastic case, size 150 x 100 x 60mm
1 small form UK secondary telephone socket (65mm square – see text)
1 3VA 230V min. mains transformer, 12V-0V-12V secondary
1 wire-ended neon indicator (no series resistor) – see text
1 8-pin d.i.l. socket
1 14-pin d.i.l. socket
1 16-pin d.i.l. socket
1 9V battery pack, with holder
2 plastic control knobs
multistrand connecting wire; single link wire; small fixings; solder etc.

Switches
1 4-way d.i.l. switch (see text)
1 3-pole 4-way rotary switch (see text)
1 min. pushbutton switch, push-to-make
1 s.p.s.t. toggle switch, 2A
1 s.p.s.t. toggle switch 1A 230V a.c.

Semiconductors
11 1N4148 signal diodes
1 1N4001 rectifier diode
1 1N5817 Schotty diode
1 2N3702 *pnp* transistor
1 2N3704 *npn* transistor
2 BUZ11A *n*-channel power MOSFET or similar
1 555 timer i.c.
1 556 dual timer i.c.
2 4017 decade counter i.c.

Capacitors
1 470μ radial elect. 16V
6 10n metallised polyester
5 100n metallised polyester

Resistors (0·25W, 5% except where indicated)

3 5k6	1 470k
3 47k	1 680k
1 100k	1 1M
1 150k	5 2M2kΩ

1 10k 0·6W metal film

Potentiometers
1 470k min. rotary carbon, lin.
1 2M2 round carbon present, vert.
1 4M7 round carbon present, vert.
1 10M round carbon preset, vert.

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signal of the frequency it was designed for. This type of sounder comprises a pivoted arm which moves a clapper between a pair of bells. In the UK it appears that these are tuned to a musical interval of a fifth to produce the familiar chord.

For the arm to vibrate most efficiently so that the bells are struck as hard as possible and so give the loudest sound, the signal must be set to the natural frequency of vibration of the system – that is, it should resonate. To achieve this, the frequency adjustment control may be used to tune the circuit for best results. In fact, tests using the prototype unit showed that the frequency is not too critical.

Circuit Description

The complete circuit diagram for the Phone Ring & Test circuit is shown in Fig.2.

Assume for the moment, that rotary selector switch S4 is set to "UK". Current flows from the 9V battery through On-Off switch S5 and diode D13. The diode provides reverse-polarity protection. Thus, if the supply were to be connected the wrong way round, it would be reverse-biased and nothing would happen. Capacitor C12 provides a reserve of charge and prevents excessive "dipping" of the supply voltage on high-current peaks.

Look at IC1a which is one section of a dual timer integrated circuit, type 556, This is configured as an astable (pulse generator) which provides a continuous train of pulses at its output (pin 5). The other section, IC1b, is also used as an astable and is associated with the single ring style phones. This will be looked at presently.

The astable frequency is determined by the values of resistors R1, R3 and R4, preset potentiometers VR1 and VR3 and capacitor C1. Ignore resistor R3 and VR3 for the moment – these are usually short-circuited by the normally on state of transistor TR1 and therefore have no effect. The reason for including them will be explained presently. Preset VR1 is used to adjust the frequency to 5Hz (five pulses per-second) at the end of construction. Capacitor C5 is for decoupling and C3 is the bypass capacitor needed for the bipolar timer.

Clock Watching

The next section is based on IC2, a decade counter. Pulses from IC1a output pin 5 are applied to its clock input, pin 14, via capacitor C6. Resistor R9 keeps IC2 clock input low between pulses and resistor R6 (in conjunction with R9) provides a discharge path for C6. On the arrival of successive pulses, each of IC2's ten outputs 0 to 9 go high in turn for 0·2 seconds, then the process repeats.

WARNING

The voltage of the ringing signal is high enough to deliver a painful and potentially dangerous shock – take extreme care when testing or while making any adjustments to the unit

IC2 output Q0 is initially high so, on the arrival of the first and second pulses, output Q1 then output Q2 go high taking 0·4 seconds altogether. There is then an off period of 0·2 seconds while unconnected output Q3 goes high. This is followed by outputs Q4 and Q5 going high, again, taking 0·4 seconds. Each high state proceeds to the "UK" contact of selector switch S4a, via one of the group of diodes D4 to D7.

Although this provides a basic UK-type ring signal, the repeat time is too short. To produce the correct delay, we need an off period of two seconds. As the circuit stands, it would give a delay of only one second (the time taken for unused outputs Q6, Q3 and Q0 to go high). To increase it, the astable is temporarily slowed down. This is done by turning transistor TR1 off for part of the cycle so that fixed resistor R3 and preset VR3 become active.

Since TR1 is a *pnp* device, it will be switched off when its base (b) is made high. However, it is kept normally on by making the base low via resistor R8. Assuming switch S1 is on, IC2 output Q7 is connected through diode D1 to TR1's base so that when this output goes high, TR1 switches off and the astable rate is reduced.

Diodes D2 and D3 are associated with IC2 outputs Q8 and Q9 and may be "switched in" by closing S2, or S2 and S3, as necessary. This, together with some adjustment to preset VR3 will provide the correct timing. With switches S1 to S3 all off, the circuit functions without additional delay and this will aid setting-up at the end.

Making the Switch

The signal at the pole of switch S4a is applied to IC4's reset input, pin 4. IC4 is a further timer i.c. configured as an astable. With its reset pin high, it is enabled and output pin 3 provides bursts of pulses at a nominal frequency of 20Hz in sympathy with the ring pattern.

The frequency is determined by the values of fixed resistors R12 and R13, potentiometer VR4, and capacitor C9. Fixed resistor R14 maintains IC4's reset input normally low and prevents false operation. Capacitor C10 is for decoupling and C11 is the bypass capacitor.

Although the signal at IC4 pin 3 now has the correct form, it is only at the nominal supply voltage of 9V so must be increased before it will ring a telephone.

Inversion

For this, the signal splits into two paths. One is via resistor R15 to the base of *npn* transistor TR2. An inverted signal therefore appears at its collector. Thus, when the base is high, the collector (c) will be low and vice versa. At the same time, a signal is obtained direct from IC4 pin 3. The two signals are applied to the gates of MOSFETs TR3 and TR4 respectively.

The MOSFETs therefore switch on in turn as each gate (g) goes high. Current flows from supply positive through either the top or bottom section of transformer T1's "primary" winding, returning to 0V via the conducting MOSFET.

Transformer T1 is a mains step-down unit used in reverse – that is, the winding intended to be the primary is used as the secondary and vice versa. Instead of reducing the voltage, it therefore increases it. Note that the labelling of the primary and secondary windings in Fig.2 refers to the way it would be used conventionally.

In this circuit, the waveform is not sinusoidal and the frequency is lower than mains frequency so the value of the final voltage is not easy to predict. However, measurement shows that it is some 100 volts peak on load using a 9V supply. This will vary between different transformers and will fall as the battery ages, but its value is not particularly critical.

Using the transformer in this way is inefficient and quite a high current is drawn from the supply – approximately 1A peak, although the average value is only about 500mA. This fairly high current drain is unimportant because the unit will not be used for long periods. The circuit will operate satisfactorily until the battery voltage falls to about 6V.

Back E.M.F.

The circuit generates a high voltage "spike" in the opposite direction to that of the supply (back e.m.f.) each time current flowing though a transformer primary half-winding is interrupted. This could destroy semiconductor devices if they were not protected. This is the purpose of Schottky diode D12 connected directly between the power supply rails.

As far as the supply is concerned it does nothing because it is reverse biased. However, to any reverse "spikes", it will be forward biased and the energy will be shunted through the diode. Note that the MOSFETs are not protected in this way but these will withstand the voltage spikes.

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PHONE RING & TEST

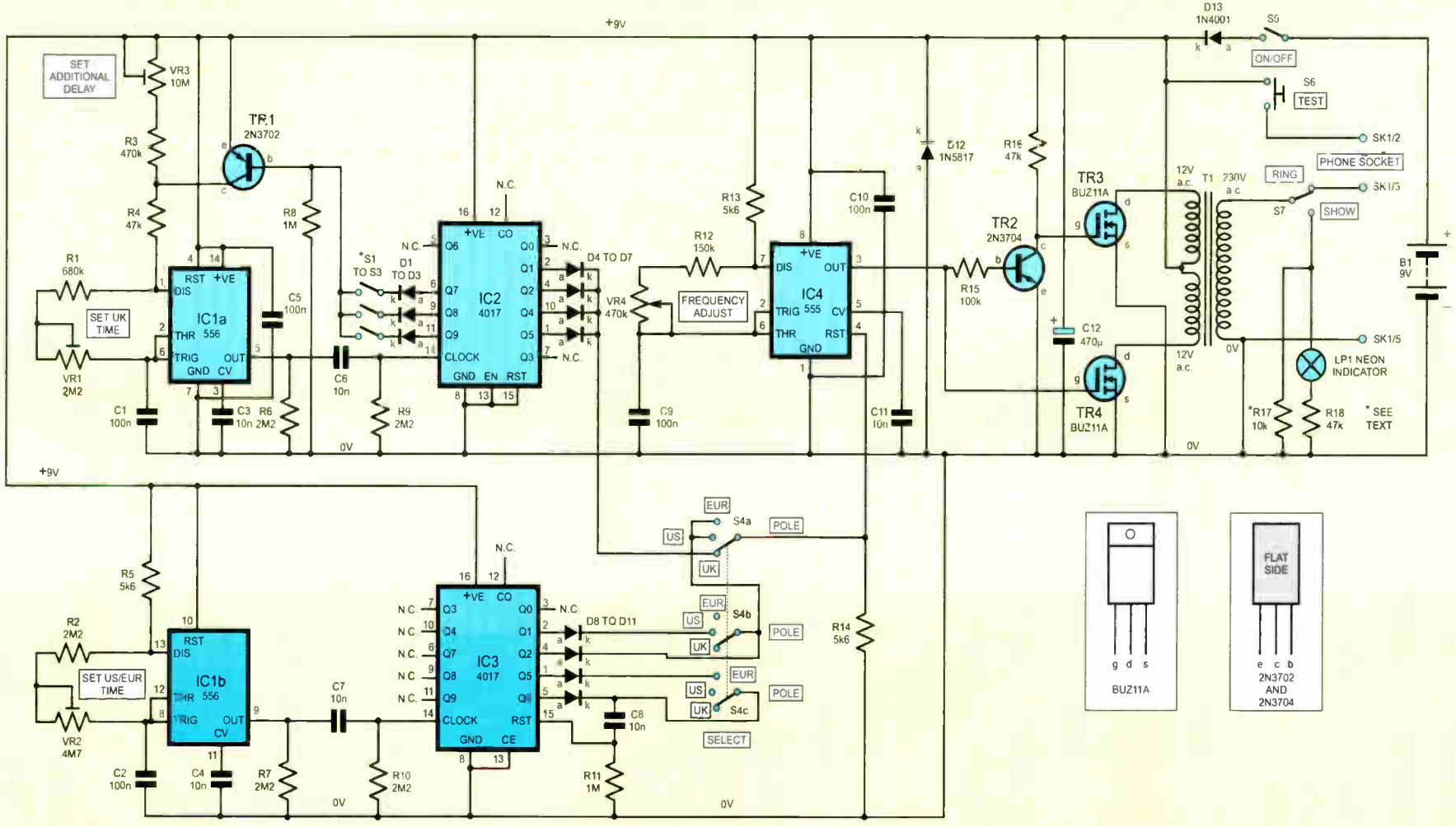

Fig.2. Complete circuit diagram for the Phone Ring & Test. Note the mains transformer T1 is used here in a "step-up" formation, i.e. instead of reducing the output voltage it increases it

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Neon indicator LP1 operates through RING/SHOW switch S7 (when set to SHOW) and resistor R18. This allows the "rings" to be monitored silently. Neon gas requires some 65 volts to conduct and resistor R18 "drops" the excess voltage and limits the current.

Operation might be unstable if the transformer output were not supplying current during the whole of a "ring". Normally, no current would be drawn until the neon "struck". Such problems are avoided by connecting resistor R17 between switch S7's SHOW contact and 0V. With switch S7 set to RING, the signal is applied to terminals 3 and 5 (ringer input) of the telephone socket, SK1.

Time Difference

Now let us look at the US ring pattern (switch S4 set to "US"). The astable centred on IC1b is now used together with decade counter IC3. Resistors R2 and R5, in conjunction with preset VR2 and capacitor C2, determine the operating frequency. Preset VR2 will be set to provide one pulse per second at the end of construction.

The pulses are transferred from IC1b output pin 9 to IC3 clock input pin 14, via capacitor C7 which operates in conjunction with fixed resistors R7 and R10 in the same way as for the UK section. Each of IC3's outputs therefore go high in turn for one second.

Since output Q0 is initially high, on the arrival of the first and second pulses, outputs Q1 and Q2 will go high, taking two seconds altogether. Switch S4b allows the signal from outputs Q1 and Q2 (via diodes D8 and D9) to proceed to switch S4a's pole, so a two-second high pulse appears at IC4's reset input (pin 4).

There follows a three second "off" period while IC3 unused outputs Q3 to Q5 go high. When output Q6 does so, a pulse is applied to IC3's reset input via diode D11 and capacitor C8 and this returns the counter to output Q0. Resistor R11 keeps the reset pin normally low and prevents false operation.

It takes a further one second for output Q1 to go high then the cycle repeats. The total "off" period is therefore four seconds. IC4 output pin 3 provides the US ring timing and its voltage is boosted by transformer T1 in the same way as for the UK signal.

To produce the European ring tone, switch S4 is set to "EUR". Selector switch S4b removes diode D8 from the circuit, so instead of a two-second "on" state, this is reduced to one second. Also, switch S4c provides a reset pulse from IC3 output Q5, via diode D10, to maintain the correct "off" time of four seconds.

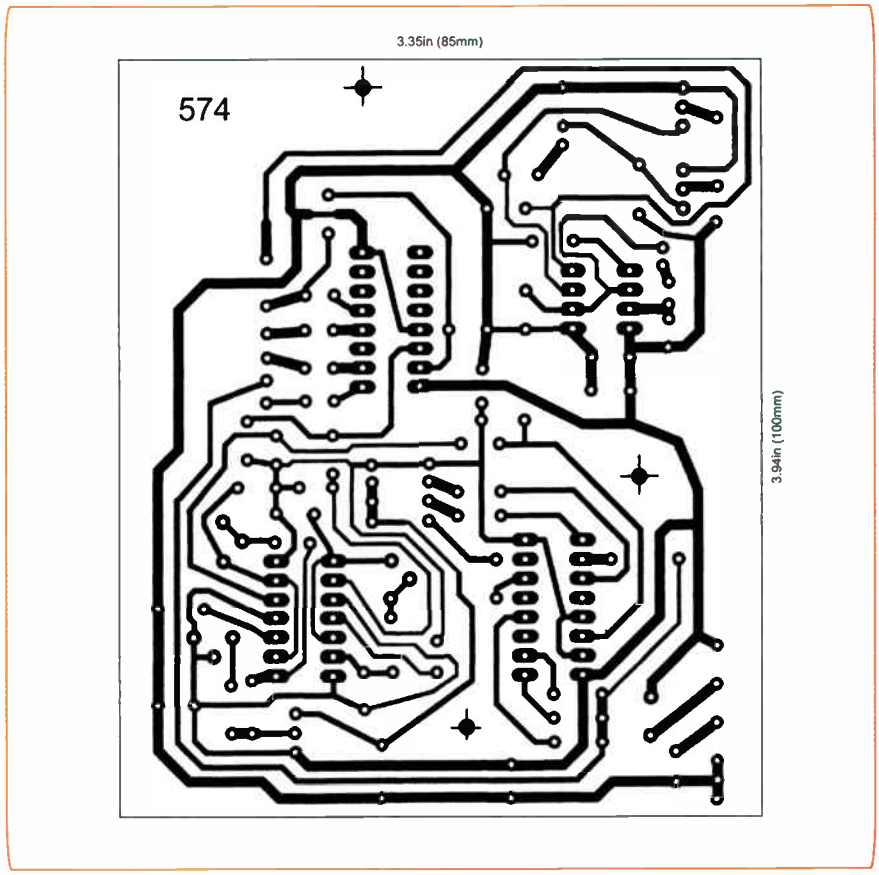

Fig.3: Full-size underside copper track master for the Phone Ring & Test board

Check It Out

Pushbutton TEST switch S6 connects the 9V supply between terminals 2 and 5 of the telephone socket. This allows the phone to operate in "talk" mode. However, since there is only one telephone involved, you will have to be content with talking to yourself!

Perhaps you have never noticed when making a call that you hear your own voice in the earpiece as well as that of the person at the other end (this is called the side-tone). Its absence is interpreted by the user as a "dead" phone. It also helps the user regulate his or her speaking volume (although in many cases it doesn't help!).

Construction

The component and track layout details for the printed circuit board for the Phone Ring & Test circuit are shown in Fig.3 and Fig. 4. This board is available from the *EPE PCB Service*, code 574.

Solder the i.c. sockets and link wire in place. Solder the four d.i.l. (dual-in-line) switches (only three are actually used but it seems that 3-way units are not readily available). Follow with all resistors, presets VR1 to VR3, and capacitors. Note that resistor R17 is situated off-board. Take care to observe the polarity of electrolytic capacitor C12.

Solder the diodes and transistors TR1 and TR2 in place, taking care over their orientation. Note that the flat face of TR1 is to the left while that of TR2 is to the right. Solder pieces of light-duty stranded connecting wire to all the points indicated – using different colours will help to avoid errors later.

To prevent possible damage to the MOSFETs, remove any static charge from the body by touching something which is earthed before handling them. Solder the MOSFETs in place ensuring that their metal tabs *do not* touch.

Perform a thorough check of the assembly so far and check that when the power is applied, +9V (battery voltage) appears at the IC holder pins as shown in Fig.2.

Insert IC2 and IC3 into their sockets, again observing the same anti-static precautions. Insert IC1 and IC4. Do not use the CMOS equivalents (7556/7555) – the specified bipolar units are more robust for the purpose. Adjust the presets to approximately mid-track position.

Boxing Up

Drill holes in the box for p.c.b. and transformer mounting, and also for a bracket to secure the batteries. Drill holes for the

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PHONE RING & TEST CIRCUIT BOARD AND WIRING

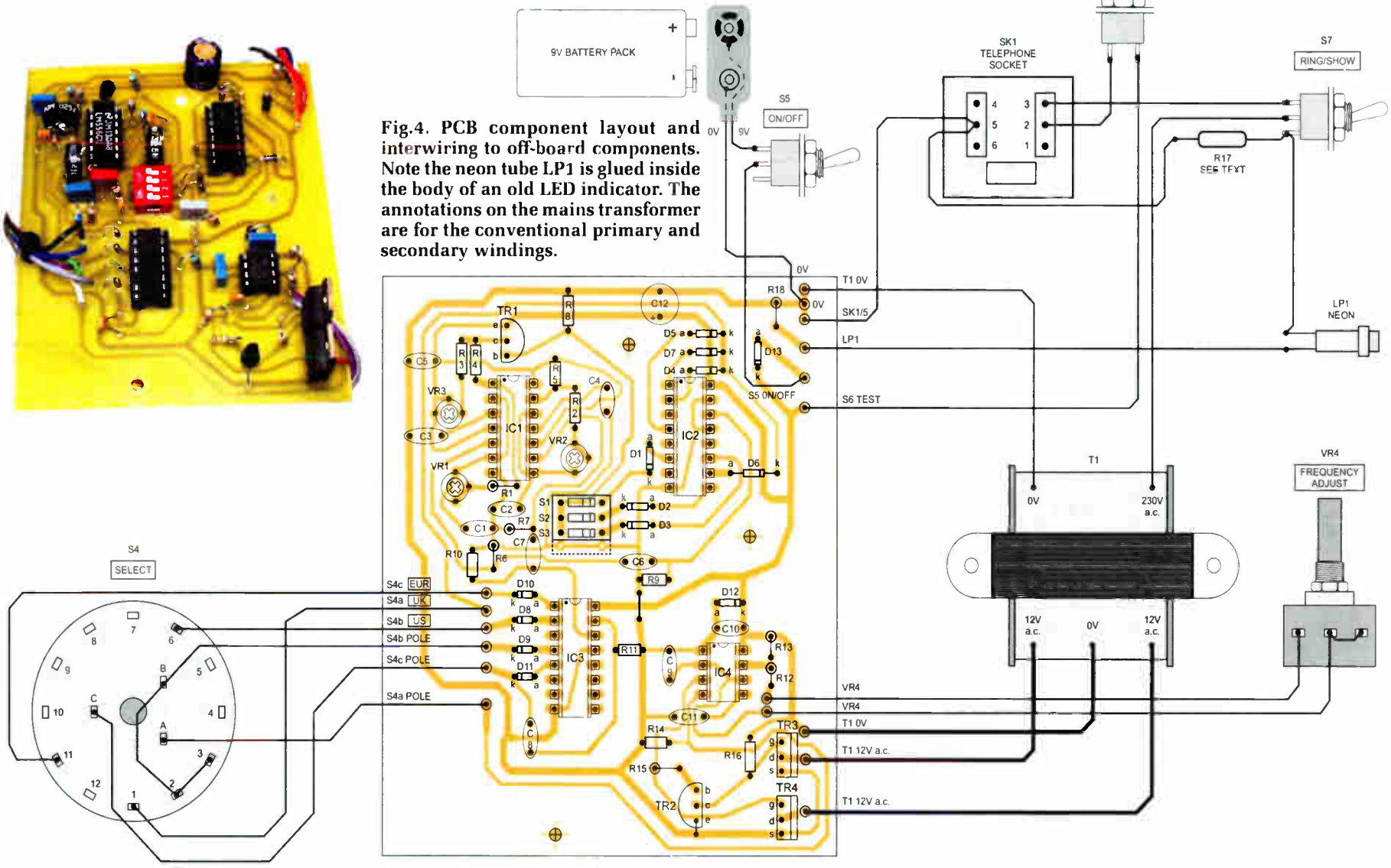

Fig.4. PCB component layout and interwiring to off-board components. Note the neon tube LP1 is glued inside the body of an old LED indicator. The annotations on the mains transformer are for the conventional primary and secondary windings.

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for the switches and for the neon indicator (the author used the body of an old l.e.d. indicator with the neon tube glued inside).

Cut a "window" in the lid for the telephone socket terminals and attach the socket (see photograph). It will be easier to use the type having screw terminals rather than IDC connectors which need a special tool to fit the wires. Readers in other countries will need to obtain the correct type of socket and wire it up in the appropriate way. Remove the securing nut and tab washer from the bush of rotary switch S4. Adjust the position of the tab so that the switch is "stopped" with only three positions.

Attach the p.c.b. on short spacers and fit all remaining parts. Refer to Fig.4 and complete the interwiring. Resistor R17 is hard-wired between the SHOW tag of switch S7 and 0V (pin 5 of the telephone socket). The diagram shows the conventional numbering of S4's tags. Apply strain relief to the telephone socket wires so that they cannot pull free when the lid is removed.

The transformer used in the prototype unit had integral leads. If the unit used has solder tags, those used for the ringer *must* be insulated so that they cannot be touched when the lid is removed. If the transformer has twin 120V primary windings, connect them in series. If there are two separate 12V windings, connect them in series with the common (c) connection taken to the mid-point.

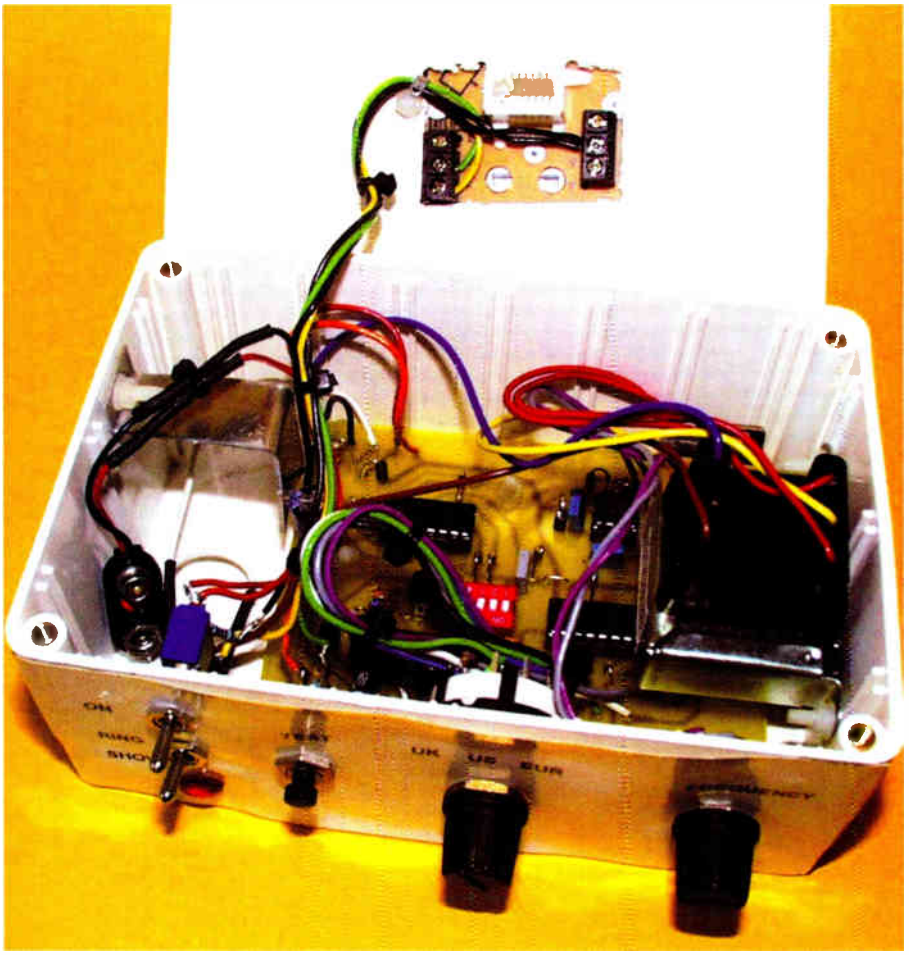
Testing

Important note: the voltage of the ringing signal is high enough to deliver a painful and potentially dangerous shock – take care while adjusting!

The circuit is best set up by observing the neon indicator (switch S7 set to SHOW). Set switches S1 to S3 Off (the bottom one in the group does nothing so may be left in either position). This disables the "additional delay" aspect of the circuit. Set Frequency control VR4 to approximately mid-track position.

Connect the batteries, set the selector switch S4 to "UK" and switch on. The neon indicator should emit double flashes. Adjust VR1 so that the time for one cycle is two seconds (30 cycles per minute). Now, switch S1 on. Re-test and note that the timing has increased.

Adjust preset VR3 so that each cycle takes three seconds (20 cycles per minute). If this is found to be impossible, switch S2 on also and, if necessary, all three switches S1 to S3.



Layout of components inside the plastic case. The transformer is bolted to one side panel and the phone socket mounted on the lid

In the Mode

It is now necessary to adjust the circuit for US and European tones. Set the selector switch to "US" – the neon should emit single flashes. Adjust preset VR2 so that each cycle takes six seconds (10 per minute). It should now operate for two seconds on and four seconds off. When switched to "Euro", it should provide one second on and four seconds off automatically. Test using a telephone (switch S7 set to RING). If you have a traditional unit, adjust VR4 to give the loudest sound.

Set switch S7 to SHOW and press TEST button S6. Speak or blow into the microphone. If you hear it in the earpiece, the speech circuit is working (ignore the fact that it may not be very loud or clear and you will hear some breakthrough of the ring signal). ***EPE***

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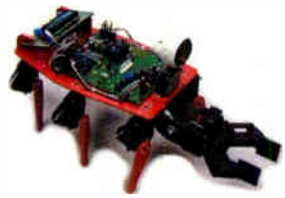

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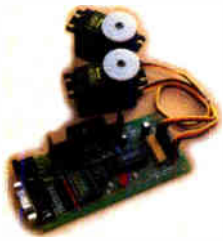

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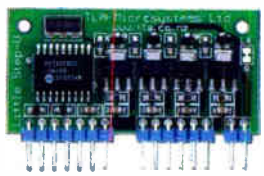

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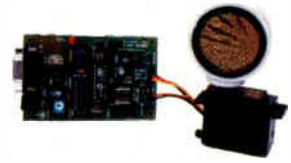

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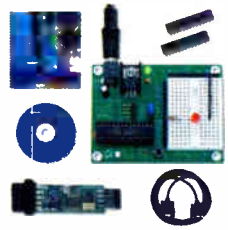

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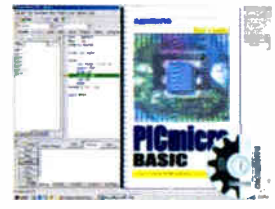

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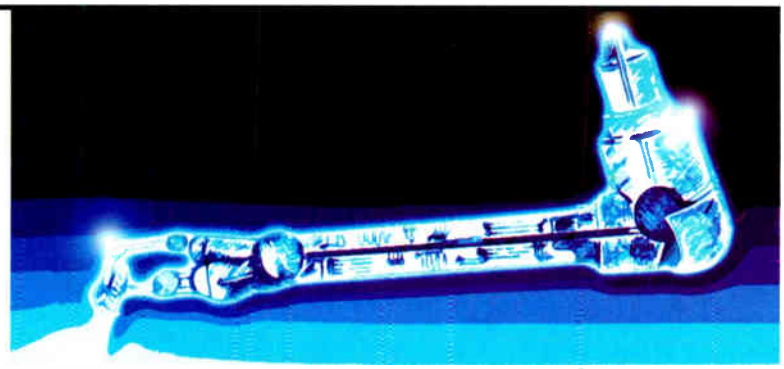

Ian Bell

Op amp Output Capabilities

THIS month we look at a query from the *EPE Chat Zone* from member ***Kenon***, which refers to the circuit in Fig.1 and raises some issues about the output capabilities of op amps:

"When the load is disconnected, the output voltage of the op amp is 5V. On the other hand, when the load is connected with the op amp, the voltage across the load is zero. I found that the output resistance of LM741 is 75Ω. Is it the problem of impedance mismatch or the op amp has not enough power to drive the load?"

The simple answer, as was quickly pointed out on the forum, is that a 5V output from the op amp into 1Ω would require 5A – well beyond the capabilities of the 741. In fact the 741 has short circuit protection, limiting the output current to 25mA, which corresponds to 25mV across 1Ω, probably much lower than the intended output voltage.

Op amp Outputs

In response to this question, we will look at the output capabilities of op amps in a little more detail, starting with the output resistance. The question also raises the issue of impedance matching, which often causes difficulties, so we will look at that too. We will also look at the output short circuit protection which enables the 741 (and most other op amps) to survive having its output shorted to ground.

The datasheet value for the 741's output resistance, as Kenon mentions is 75Ω. However, the output resistance of the inverting amplifier configuration used in the circuit in Fig.1 is much less than this due the beneficial effects of the negative feedback used. Fig.2 shows Fig.1 redrawn for looking at the output resistance.

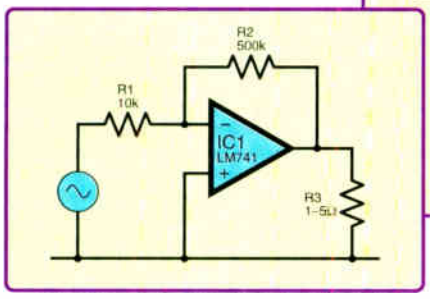

Fig.1. Kenon's original circuit

In Fig.2 we have removed the troublesome load, included a voltage source to represent the op amp's output signal, and added a resistor to represent the output resistance of the op amp. The full analysis involves setting $V_{in} = 0$, applying a voltage to the circuit output and finding the resulting current. We will just skip to the result.

Finding Output Resistance

The output resistance of the inverting amplifier circuit as a whole, R_{Out}, see Fig.2, is related to the output resistance of the op amp, R_O, by

$$R_{Out} = \frac{R_O}{1 + \beta A}$$

where A is the open loop gain of the op amp and β is the feedback fraction, that is the proportion of the output signal that is fed back to the op amp's inverting input. This is given by the "potential divider formula" for R_1 and R_2.

$$\beta = \frac{R_1}{R_1 + R_2}$$

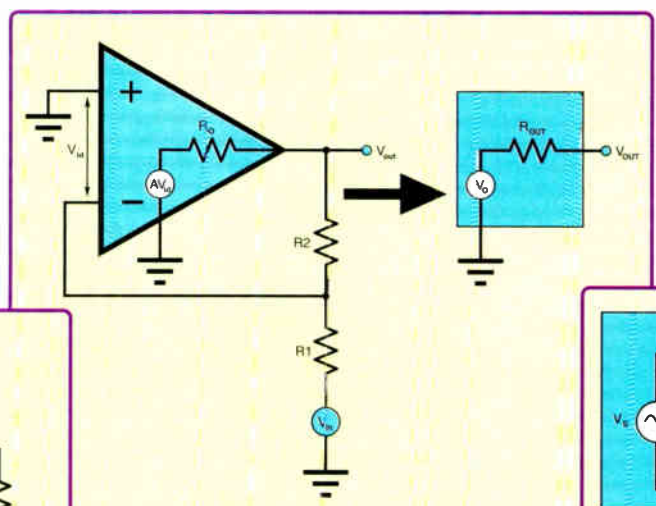

Fig.2. Inverting op amp amplifier showing op amp output resistance, R_O, and equivalent circuit for the complete amplifier with output resistance R_{OUT}

For Kenon's circuit R_1 = 10k and R_2 = 500k so β = 10/510 = 0·0196.

For a typical open loop gain of 200000 for the 741 (quoted as 200V/mV on the datasheet) the output resistance is just under 0·02Ω:

$$R_{Out} = \frac{75}{1 + (0{\cdot}0196 \times 200000)} = 0{\cdot}0191\Omega$$

Now we know the output resistance we can consider matching and loading. Although we have already stated that the problem with the circuit is due to overloading, we can have a look at matching and see if that is a problem as well. We will imagine for a while that the op amp's output current is not limited.

There are a number of different scenarios and problems which could be put under the heading of "matching", but here we have what is probably the simplest case – that of a source with resistance R_S connected to load of resistance R_L as shown in Fig.3.

Matching

The matching problem is basically one of choosing the most appropriate R_L given that we know R_S (or vice versa). Of course if R_L and R_S are already determined we can work out what is going to happen using the same theory.

The two resistances in Fig.3 form a potential divider. Thus the voltage across the load is given by:

$$V_L = \frac{R_L}{(R_S + R_L)} V_S$$

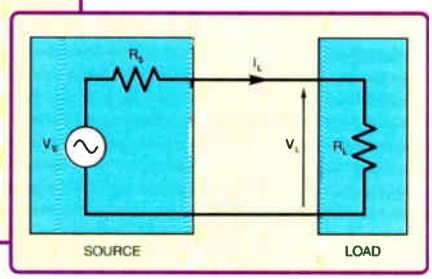

Fig.3. A source and load connected together

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We get this equation by using Ohm's law to get the current through the two resistances (V_S divided by the total resistance: R_L plus R_S) and applying Ohm's law again to get the voltage drop across R_L (by multiplying the current by R_L).

From the equation we see that if we want V_L to be as large as possible then R_L must be much larger than R_S. If R_L is very much larger than R_S then the load voltage is effectively equal to the source voltage.

The current in the load is given by

$$I_L = \frac{V_S}{(Z_S + Z_L)}$$

Thus if we want the current in the load to be as high as possible we need to make Z_L much smaller than Z_S. As might be expected this is the opposite requirement to the one for maximising the voltage across the load.

Unmatched Load and Source

Given that the term "matching" might imply $R_S = R_L$, the two scenarios we have just looked at – maximum V_L by making R_L much larger than R_S, and maximum I_L by making R_L much smaller than R_S, indicate what happens when load and source are not "matched". However, in general we should really be asking *what is the most appropriate load for this source?* – matching in the sense of $R_S = R_L$ is not always what we want.

For example (briefly moving away from the specific circuit we are looking at here), a high impedance input (R_L much greater than R_S) may be most appropriate for amplifying the voltage from a sensor (here R_S is the sensor output resistance and R_L the amplifier input resistance). Similarly, Kenon may want the output voltage to be unaffected by the load so that we get the required voltage gain (50) from the circuit, thus again we would need R_L to be much greater than R_S.

The loss of (voltage) signal in decibels due to loading (load loss) can be calculated as follows:

$$\text{Load loss} = 20_{\log}\left[\frac{R_L}{(R_S + R_L)}\right]$$

In general it is a good idea to have R_L about ten times as large as R_S if you want to maximise the voltage signal. This results in a load loss of less than 1dB.

For Kenon's circuit (assuming that voltage across the load is the important factor, not power to the load, and still ignoring the fact that the 741 is actually overloaded) we would get a loss of 0·17dB for $R_L = 1{\cdot}0$ and $R_S = 0{\cdot}02$. This result just serves to highlight that the lack of output voltage is due to *over*-loading rather than "matching".

The circuit fails to produce the required output voltage because it is not capable of delivering the required current, rather than because the output resistance is too high. Of course, once the op amp goes into overload and switches on its protection circuits the conditions under which the output resistance was calculated no longer hold and value does not really mean anything.

It is also worth noting that the open loop op amp output resistance of 75Ω would lead to a load loss of 38dB with the same load (again assuming no overloading), demonstrating the strong effect of feedback on circuit behaviour. When working with op amp circuits it is important to remember that the *circuit's* characteristics are not necessarily the same as the *op amp's*. The amount of feedback and specific circuit configuration used must be taken into account.

Power Transfer

To broaden the discussion on matching for a moment, consider what happens when $R_S = R_L$ – why might this be useful? The answer is that maximum *power* is transferred from source to load. In order to prove this you have to use calculus to find the maximum of the relationship between load power and load resistance.

The power transfer aspect of matching is important in power amplifier outputs. For example, consider a power amplifier producing a 3V RMS signal with 1Ω output resistance; the power into loads of various resistances are listed below. The maximum power is obtained for a load of 1 – matching the source resistance. The maximum power delivered to the load is half of the power taken from the source at that point, as the load resistance increases above being equal to R_S a greater proportion of the source's power ends up in the load, but the actual power delivered decreases.

Load	*RMS Power in Load* (1Ω source at 3V RMS))
0·25Ω	1·4W
0·5Ω	2·0W
1Ω	2·3W
1·5Ω	2·2W
2Ω	2·0W
3Ω	1·7W

It is worth pointing out that Fig.3 does not apply to all situations where the issue of matching may arise. An important case is high frequencies on long wires, where the wire must be considered as a transmission line. We then have to model the wire between the source and load rather than assuming a simple connection. Secondly, not all "sources" are really sources in the sense of Fig.3. For example, some sensors vary in impedance, but do not contain a voltage source.

Short Circuit Protection

As we have already said, Kenon's circuit will cause the 741 to activate its short circuit protection. To see what is going on we have to look inside the op amp. Fig.4 shows the 741's output circuit (μA741 from Texas Instruments **www.ti.com**). Note that other sources on 741 schematics may vary from the one given, but the basic configuration should be similar.

Fig.5 shows a simplified version of the output circuit with the protection circuit (TR4, TR5, R1, R2) removed and biasing circuitry (TR6, TR7, TR8, R3, R4) simplified to a current source and two diodes. The diodes are the base-emitter junctions of TR7 and TR8. Hopefully, Fig.5 makes it easier to see that the circuit is basically a push-pull emitter follower in which TR1 conducts for positive signal voltages and TR2 for negative voltages.

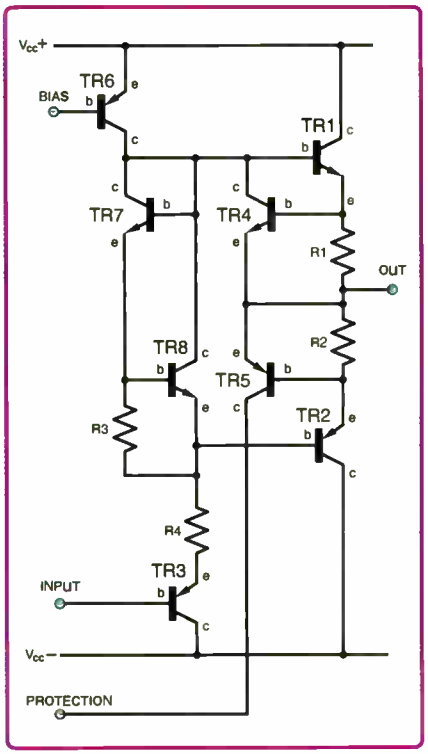

Fig.4. The μA741 output circuit (from TI data sheet)

As the input signal varies, the diodes maintain a constant 2 × V_{BE} difference between the two base voltages ensuring that they are both biased to the point of just conducting with no signal present. The actual base voltages will vary with the signal, but the difference between them is fixed by this biasing arrangement. The diodes are ideally at the same temperature as the output transistors so that changes in their voltage drop with temperature tracks those of the output transistor.

The push-pull amplifier is likely to be damaged if its output is short-circuited to ground due to the excessive collector current which will flow in the conducting transistor. Part of the short-circuit protection circuitry is shown in Fig.6. The protection circuitry monitors the current flowing in the output and turns off the output transistor if the current exceeds some pre-defined limit. The current detection is achieved by using a small resistor (R1, about 22Ω) in the output signal path, and a transistor to switch off the output.

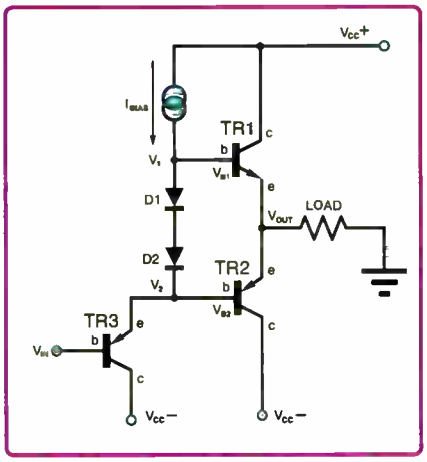

Fig.5. Simplified output circuit

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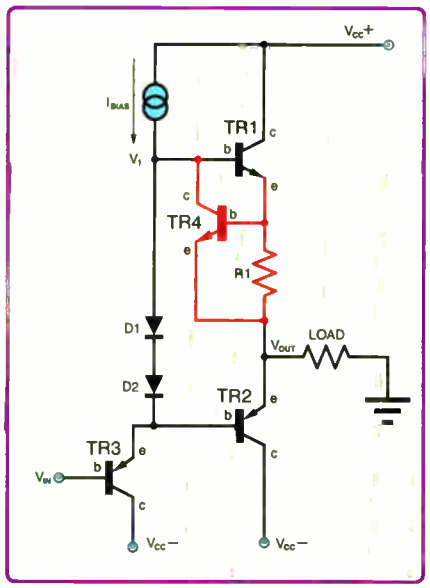

Fig.6. Output stage with part of the protection circuit (protection circuit is shown in red)

The output current causes a voltage drop across the resistor. The protection transistor (TR4) switches on when the resistor voltage reaches 0·55V to 0·6V . The protection transistor is connected so that when it is on it effectively short-circuits the input to the power transistors, so they have no signal to amplify.

The protection resistor values, R1 = $pV_{BE\ TR4} / I_{max}$ where $V_{BE\ TR4}$ is the turn-on voltage of the protection transistor (typically 0·55V) and I_{max} is the maximum output current, i.e. the current at which the protection kicks in. For R1 = 22Ω and $V_{BE\ TR4}$ = 0·55V we get a current limit of 25mA.

The other part of the protection circuit, TR5 and R2, works in the same way but connects back to earlier in the circuit to also switch off other transistors which would otherwise be subject to excessive power dissipation.

Which Op amp?

As the 741 is not capable of driving the loads required by Kenon's circuit, the question arises as to what might do the job. One possibility, particularly if voltage amplification is the key requirement, is to use a high power op amp. For example, the LM675 from National Semiconductor is capable of delivering output currents in excess of 3A, operating at supply voltages of up to 60V. The OPA541 from Texas Instruments is capable of operation from power supplies up to ±40V and delivering continuous output currents up to 5A. Another possibility, if power amplification is the main aim, would be to use a power amplifier IC (such as an audio power amplifier).

A search of manufacture's web sites will provide more devices to investigate. In all cases the data sheets need to be consulted to check the suitability for the application. Many power op amps are designed for use in circuits with gains of five or 10 or more (not a problem here). If the load is capacitive or inductive, then the ratings of the device may be reduced and special circuit techniques may be advised on the datasheet. Correct heatsinking is also essential for success with high power ICs.

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Net Work

Alan Winstanley

OUR Internet column continues with our theme of using Skype, the free Internet-based telephony and video calling service. Having set up the Skype software as described previously, try clicking your own name in the contacts list followed by the Edit My Profile button: instead of the default "head and shoulders" icon, click Change.... and point to an image or logo on your hard disk. Skype will resize it and your graphic will now appear against your name in all your friends' contact lists.

You can also right-click Skype usernames in your contacts list and change them to something more recognisable, for example instead of "fredsmith1927057" you could rename it to "Fred".

If you are gathering quite a number of entries in your Contacts list, trying sorting them into Groups to manage them (e.g. friends, workmates): go View/Show Contact Groups and then drag names to the appropriate labels.

VoIP Phones

For those users who want to get into Skype in a big way, they might consider using a dedicated VoIP (Voice over Internet Protocol) telephone instead, which offers a more familiar-feeling way of communicating with fellow users. A number of new VoIP phones are coming onto the market that are certified for use with Skype: simply plug them into a PC's USB port and install the phone's USB drivers, and then use the handset to call Skype users for free, or ring non-Skype telephone numbers anywhere in the world using "SkypeOut" credits. Quality and price varies, and one cheap unbranded VoIP phone tested by the writer failed to work at all and was scrapped.

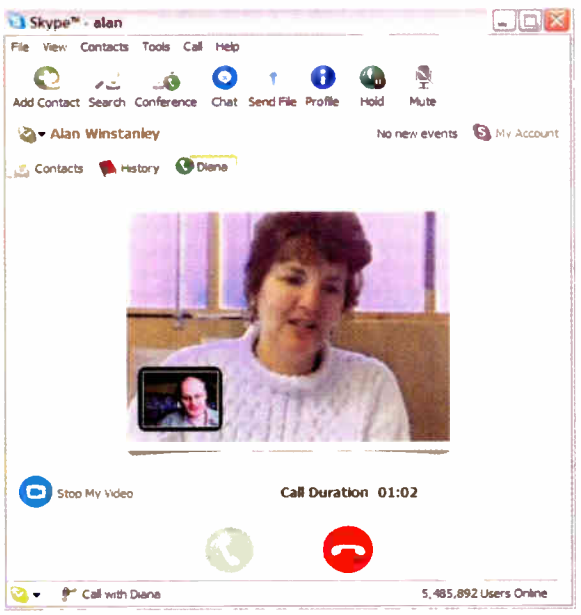
More sophisticated phones may have a built-in address book and other features including mono or colour LCD display, and some may offer wireless operation, such as the Qpe Wireless VoIP Phone from Maplin (**www.maplin.co.uk**). On the web, Watford Electronics (**www.savastore.com**) currently offer the US Robotics USR809600 VoIP USB Skype phone for just £20 which is good value compared to unbranded ones. It has an LCD display and supports Skype Caller ID. They also list the interesting-looking Linksys CIT200-UK DECT cordless Skype Handset for £71.

Displaying a trend towards converging communications, "hybrid" phones are emerging with Panasonic introducing their new Skype compatible KX-TG9000 handset in some countries: it connects to a POTS landline as well as to a broadband connection, so you can choose how to route your calls.

Possibly the neatest alternative of all is to try a Bluetooth cordless headset for hands-free use with a PC. In the writer's own experience, setting up Bluetooth on a PC has always been a troublesome process. A USB Bluetooth dongle is required (note, Class 1 Bluetooth devices have a 100 metre range – Class 2 types are limited to about 10 metres), but be prepared for plenty of hairpulling when trying to make Bluetooth devices talk to each other. Some technical hints and tips on Bluetooth headsets may be found in a Skype forum at **http://tinyurl.com/9kj3j**.

Video Stars

One of Skype's major benefits is the ability to video-communicate with friends and relatives no matter where they are in the world. Seeing and hearing distant family and friends in this way can be a hugely rewarding and enjoyable experience. Not only will Skype play the contact's video image live in a window, a small thumbnail of yourself is also provided (see screenshot). Full screen video can also be selected.



A Skype video call in progress, with a thumbnail self-image. Full screen video can also be selected. Note the Hold and microphone Mute buttons in the toolbar

It should be pointed out from the start that neither sound nor vision will be perfect: expect some sound lag at times and occasional pixelation of images. Performance seems to tail off in the evening as general Internet traffic increases, but overall the quality of Skype video is more than acceptable – especially as it's free. Sometimes, sound performance has also been astonishingly good.

A web camera is needed and in this respect buyers are spoiled for choice. Try checking your digital still camera for a webcam or "USB Cam" mode that allows a direct connection to a computer. A small desktop tripod can be bought for a few pounds and a separate microphone will possibly be required; a mains adaptor for the camera may be useful. Note that a number of digicams have a "video out" mode but this may be intended for displaying digital images on a television screen. This is not suitable for Skype video.

Most users will probably opt to buy a dedicated webcam. As always, you get what you pay for and popular brands include Logitech, Creative and Philips (e.g. see **www.amazon.co.uk**). They are USB connected and may have a clamp to fit them on top of an LCD monitor or laptop. Also look for a built-in microphone, a snapshot button and an "on air" l.e.d.; some webcams include a separate privacy headset as well. Image resolution is measured in pixels: almost all seem to offer native VGA 640 x 480 pixels, which is perfectly adequate for webcam use.

The author's Logitech 5000 camera is somewhat bulky but has an extra-wide field of view to allow family members to appear in one image with less distortion. It also has a pop-down privacy visor. Sound quality via the integral microphone is good (remember to make a test call to Skype to check out your sound system – see last month).

The more expensive cameras such as the Logitech 5000 and the Philips SPC 900NC include intelligent face-tracking software which is quite eerie to behold: it zooms in or "electronically" follows the subject around the room (within limits) without physically moving. (Unfortunately the current Skype software seems to forget these default settings in between sessions.)

Next month, I will outline some alternatives to Skype that will enable you to use an ordinary telephone on your broadband connection. You can Email the writer at **alan@epemag.demon.co.uk**

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READOUT

Email: john.becker@wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

Interak and Greenbank

Dear EPE,

Firstly, the new magazine style looks superb – much better quality overall, the diagrams and schematics are clearer and a pleasure to read.

Secondly, it was great to see the letter from David Parkins (*Readout* Jan '06), as he is someone whom I had not heard of for almost 20 years. I had searched for links to him on the Internet but had been unable to find any.

His letter contained some thought provoking comments and really anyone who writes to your magazine with some criticism is only doing so because they do not want to loose a rare and valuable publication. As David says – he has "seen most of them come and go" and electronics magazines are now rarer than hens' teeth.

During the 1970s and 80s, David was the guiding force behind the Interak computer, this was closely linked to his business Greenbank Electronics. I still use this computer today (it could be the only one left now), which is a Z80 based rack and card system. My system uses CP/M 2.2 as an OS, although there were many other options. The computer was built up by buying specific cards from Greenbank or making your own using a prototype card.

What makes the Interak such a great computer is that it is so versatile – it is really easy to expand and adapt so that almost any type of circuit can be connected to it. Of course it does not have the amazing graphics capability of modern PCs but I find it ideal as a reliable electronics workhorse.

When the Interak was being sold, David went to great lengths to ensure that his customers were satisfied and the after-sales service was outstanding. I think he would agree that he is something of a perfectionist and this shows in his attention to detail in the copious documentation and circuit diagrams. If he could be persuaded to write some articles on the life and times of Greenbank Electronics I'm sure they would make very interesting reading.

My keen interest in electronics means that I am curious to know what effect every byte and bit are having and I like having control of what goes where in the memory – with today's PCs this is almost impossible. The Interak allows complete control of every function, it is also great for robotics plus it is fun to use. There are many features of this computer which I find really appealing!

My present project is to use a Compact Flash card as a hard drive storage device. Since most CP/M applications use 20K or less a 64MB Compact Flash will provide more than enough storage. The recent *EPE* articles on Compact Flash were a great assistance and so far I can read the CF Identity Information. I am presently modifying the BIOS to be able to read and write files from the CF.

Regarding the *Readout* issue of programming languages, it depends what you want from your hobby/interest. I appreciate that there are some brilliant high-level languages around now and I can understand some people being very enthusiastic about their favourites but (and please correct me if I am wrong) I see *EPE* as a practical "hands on" type of publication. I have seen other magazines which cater exclusively for software and because of the vast number of languages around, *EPE* would soon be overburdened in an effort to please everyone.

The languages I use are Z80 assembler, PIC assembler, PicBasicPro, BASIC and Visual Basic. I enjoy assembler because I can (usually) picture the operation of every bit as it is controlled by the code. These few languages seem to be sufficient for my needs at present, which are control and testing of electronic circuits. It would also be interesting to see notes on other languages and perhaps the reason why they work with a particular project. In some cases though, I would question the point of using a high-level language to operate an electronic door lock or for many of the other projects in *EPE*.

Alan Paton, via email

Thanks for an interesting letter, Alan. I don't think I knew of David's Greenbank/Interak connection, although Mike would have done.

I agree with EPE's attitute towards languages. For many years I've standardised on PIC assembler and VB6, which do all I want and are interesting to use. You may see a little coverage of other languages from time to time, but we always have to consider what most readers appear to have in terms of facilities and knowledge, and we are not really a "programming" mag in the wider sense.

Increment-Decrement

Dear EPE

I am busy with a PIC program using an LCD, but I am struggling – please help! I have written the program for a PIC16F84A. The program counts up and down in BCD with LEDs as outputs. When the circuit increments, the LCD must display the message "WELCOME". When it decrements, the LCD must display the message "GOODBYE". When the count reaches 99 the LCD must display the message "FULL".

Gordon Mofokeng, South Africa, via email

I regret that we don't normally have time to offer design advice to readers in this way, Gordon, but you might raise the question of your problem on our Chat Zone, *access via our main page at* ***www.epemag.co.uk*** *and see if any readers might care to advise.*

But it seems that you could simply use subtraction of your previous count value from the current one to find increment or decrement conditions, reading the Carry/Borrow bit of Status to detect greater than or less than, and then using an equality check of the value of 99 with the count value i.e.:

```
movlw 99          ; put 99 into W
xorwf Count,W     ; XOR with value in
                  Count
btfss Status, Z   ; is answer equal to 0?
return            ; no
goto Full         ; yes, action display
```


World Radio History

Electrovalue

David Longland of Electrovalue recently wrote direct to Alan Winstanley regarding our website "history" page:

I am at last emerging from a cloud under which I sank in Sept last year when I had to close down my company, Electrovalue Ltd. Someone told me there was "talk" on the internet on the hole left on our closing. You are running a good chat site which I found this afternoon and also a bit of history promoting fond memories, on **www.epemag.wimborne.co.uk/history2.htm**.

Many times in the past I have been asked whether we are an offshoot of RS Components, which we were not. I presumed that is was a confusion on their part between Electrovalue and Electrocomponents, the RS holding company. However on reading *history2*, it says that "RS later launched ElectroValue". If this was published, then this could have been the origin (I have no problem with it). I started my company in 1964 trading as "Longland's" and advertised in *Practical Wireless*, later in *Practical Electronics*. In Nov '65 I registered the name Electrovalue and started trading as that.

Anyway, its nice to make contact with the old world and now I'll continue with my retirement.

David Longland, via email

Alan replied to David:

It is very good of you to write, David, and we're pleased to hear from you again. I've copied it to John.

It came as a huge shock to me to learn that you had ceased trading. I always had a healthy respect for the extremely interesting range of components that you sold, and especially those tricky parts – LED bezels, C&K miniature toggle switch dress nuts and PVC tang covers, and the famous range of Siemens components, RF parts and filters. Alfac transfers and Seno GS etchant. All the quality parts that made my projects look good. And you listed the first blue LED that I ever saw (£30!)

I was aware you were independent of RS, but now that you mention it, I have not until now connected your Electrovalue name with that of the RS offshoot (the RS catalogue with a different cover – was it ElectroSpares I now ask myself?). Now I'm not sure any more! Perhaps John knows.

If there is any error on my web pages then I would definitely like to correct it, and also I'll add your comments into the text as I'm sure readers will be pleased to see them.

It is encouraging if you feel able to turn the corner after having endured such a shock. One thing I have learned in life is that what seems like the end of a road usually turns out to be a bend. So I hope something new comes up that will help you along again.

Alan Winstanley

I replied to David and Alan:

David, I'm very sorry to learn about Electrovalue closing. You have been one of the stalwart names for many years. The marketplace will miss you. But Alan's right; my own similar statement is that as one door closes another can open, sometimes with great benefit, as I've discovered over the years.

Alan, Electromail was the RS outlet! Certainly Doram (the Door to Amateur electronics) was another, but that went long before Electromail.

All our very best wishes David.

Digital Terrestrial TV Again

Dear EPE,

Just thought I would drop you a line in reply to Ken Wood's letter in *Readout* April '06 about Digital Terrestrial TV, and also the comments about remote control ranges.

There is a device already available to convert the video output from a digital receiver to an analogue RF signal. This is an RF modulator and some have either a Scart input or an RCA phono input that converts from composite video to RF on the standard coaxial connectors. They can also be tuned across the analogue band between channels 21 to 69 thus giving an interference-free picture.

The modulator can be fitted on the output of the Freeview box connected via the Scart output, the RF from the modulator then connects into the VCR on the system then the output from here is "piped" into the distribution amplifier and fed to the various outlets around the house.

The setup of the modulator can be a little tricky and usually results in an initial poor quality picture, this is usually attributed to being on the same frequency as a terrestrial TV channel or maybe the same frequency as the VCR! This in effect generates an RF signal of its own through its own internal modulator. A simple way to fix this problem is by tuning the modulator to a different frequency, clear ones can be found by tuning the TV or VCR to what can be seen as a "blank" area on the band i.e. just snow. (If you do get a poor picture just unplug the modulator and see if there is a faint signal in the background, dead giveaway!)

The modulators usually have an aerial input as well as output so the existing terrestrial aerial can be fed through it. If this is a problem then an aerial combiner or diplexer can be used. This connects two aerial inputs to one output.

The remote control can be assisted using a remote extender. This is a two-part device that has an infra red receiver and transmitter. They convert the signals to RF between them and the most common look like pyramids. The receiver goes next to the TV or other equipment to be controlled. The transmitter goes usually in the bedroom or wherever the control is being used, the remote is aimed at the transmitter and an RF signal is sent to the receiver that converts the signal back to infra red. It was mainly used for remote control from the bedroom down to the living room.

The components are available from CPC, **www.cpc.co.uk**, RF modulator SR05358, at approx. £35 and from **http://cpc.farnell.com/jsp/endecaSearch/partDetail.jsp?SKU=AVVRX569**, at £13.61.

Dave Barsby, via email

Modulators used to be far more common, Dave. I recall buying little oblong tins with them in and used them for all sorts of purposes. Then along comes Channel 5, *which transmits on a similar frequency, and which I used, and indeed was set in my VCR at the time, and which became unusable. When C5 started locally (I live not far from the Crystal Palace transmitter), teams of C5 reps went round households with such VCRs and somehow retuned all the modulators in them. But ours never seemed the same again. Got DVD now and am not sure what they use, if at all.*

PIC Development

Dear EPE,

Over the past couple of years I've noticed quite a large amount of cheap and cheerful electronic games and gadgets being sold that contain both an LCD display and some kind of input device, some including a full qwerty keypad. This got me thinking that these would make ideal low cost development systems for a PIC.

Most PIC projects seem to require an LCD and every one some kind of human input device so why not cut down on hardware building and modify one of these devices?

I have actually already read all the *EPE* articles on LCD interfacing etc. I'm now interested in developing smaller and cheaper handheld units though as the standard keypads and LCDs you buy for hobby development are rather large and also expensive.

This is what made me think of all the current cheap handheld devices that are about and could possibly be used for other purposes. So far, all the devices I've dismantled to investigate use a "die on board construction" which makes the product cheaper to produce but also impossible for anyone to experiment with.

I was wondering whether maybe one of your readers has had a similar idea but has actually managed to find a useable device (i.e. one where it's actually possible to connect to the LCD, keypad and micro.)

Lee Archer, via email

Lee, at various times I've shown in EPE *how to interface LCDs, GLCDs, keypads, keyboards and mice to PICs, but you've obviously read them. You could also ask the question via our* Chat Zone *(access also via* ***www.epemag.co.uk****). Readers, any suggestions for Lee?*

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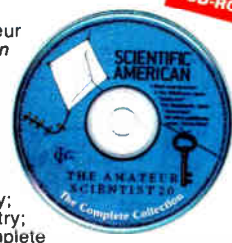

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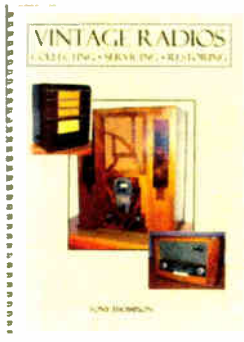

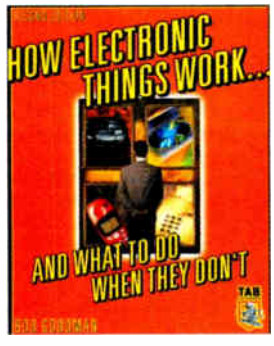

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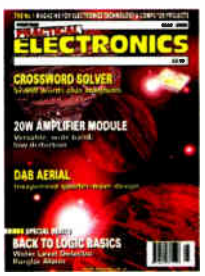

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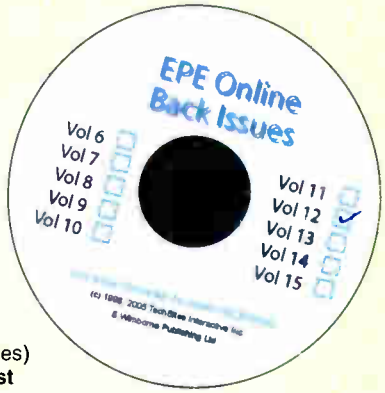

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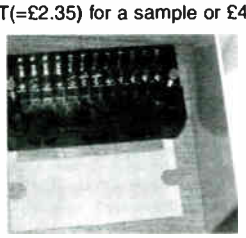

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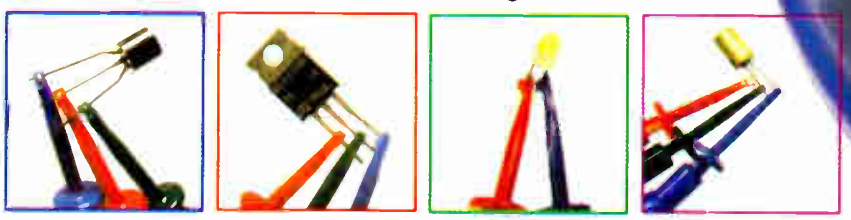

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